Ecosystems Approach to Assess Multispecies Fisheries Risks from Exploitation and Environmental Changes

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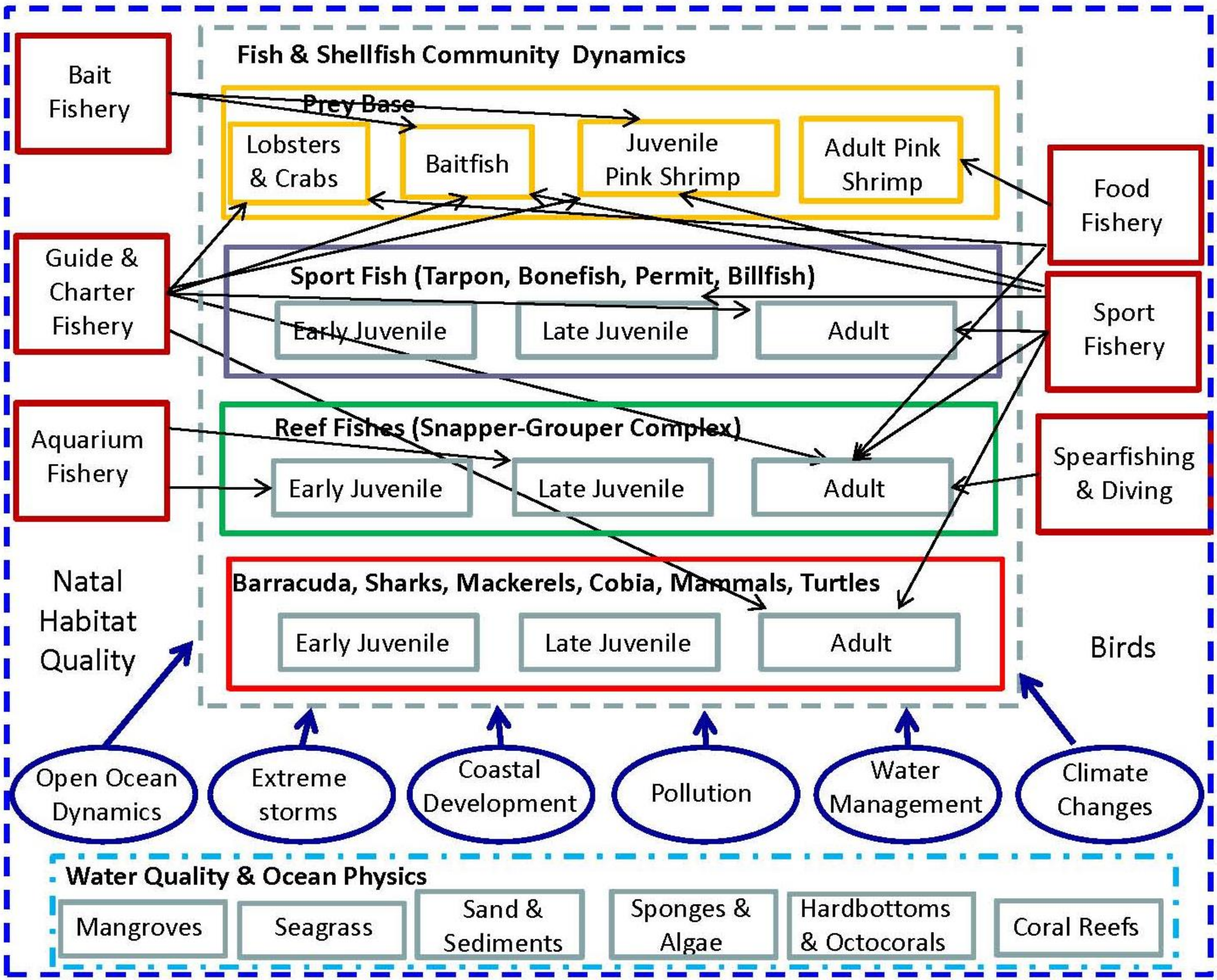
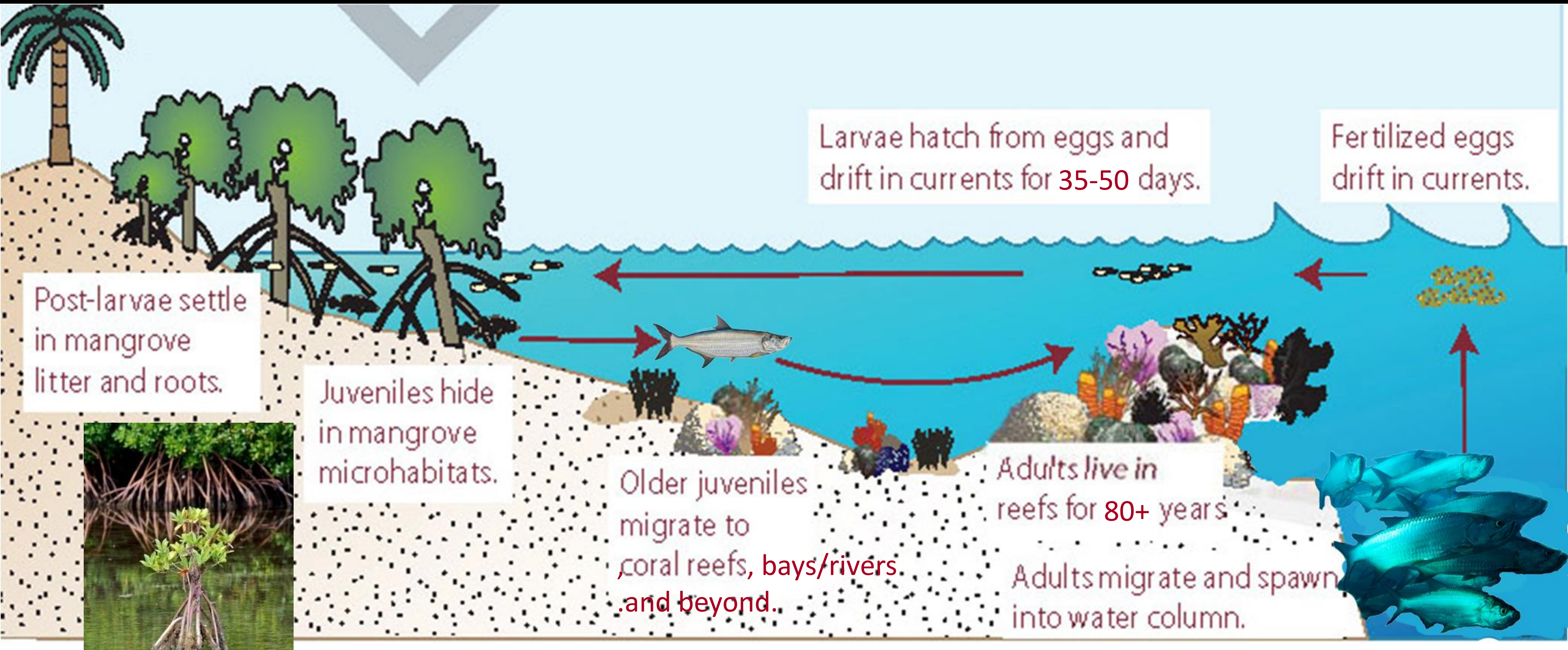
UNIVERSITY OF MIAMI

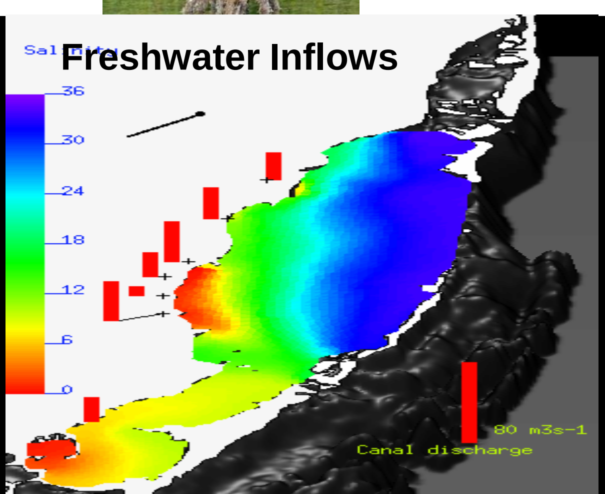
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

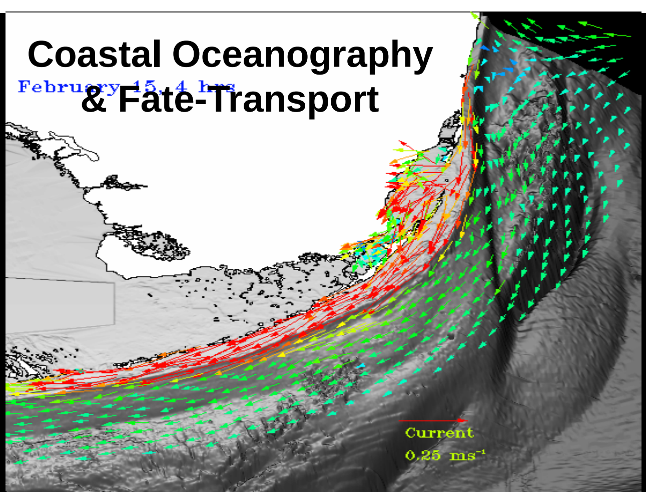
Ecological and fishery inter-relationships of the southern Florida ecosystem

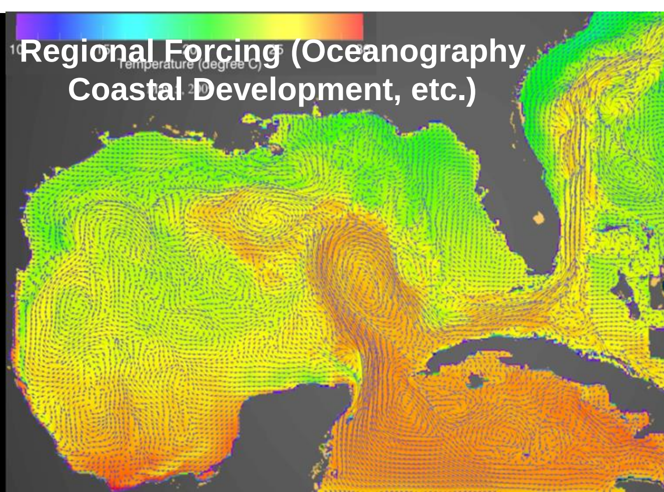


Coastal Oceanography & "Habitat" Use Ontogeny



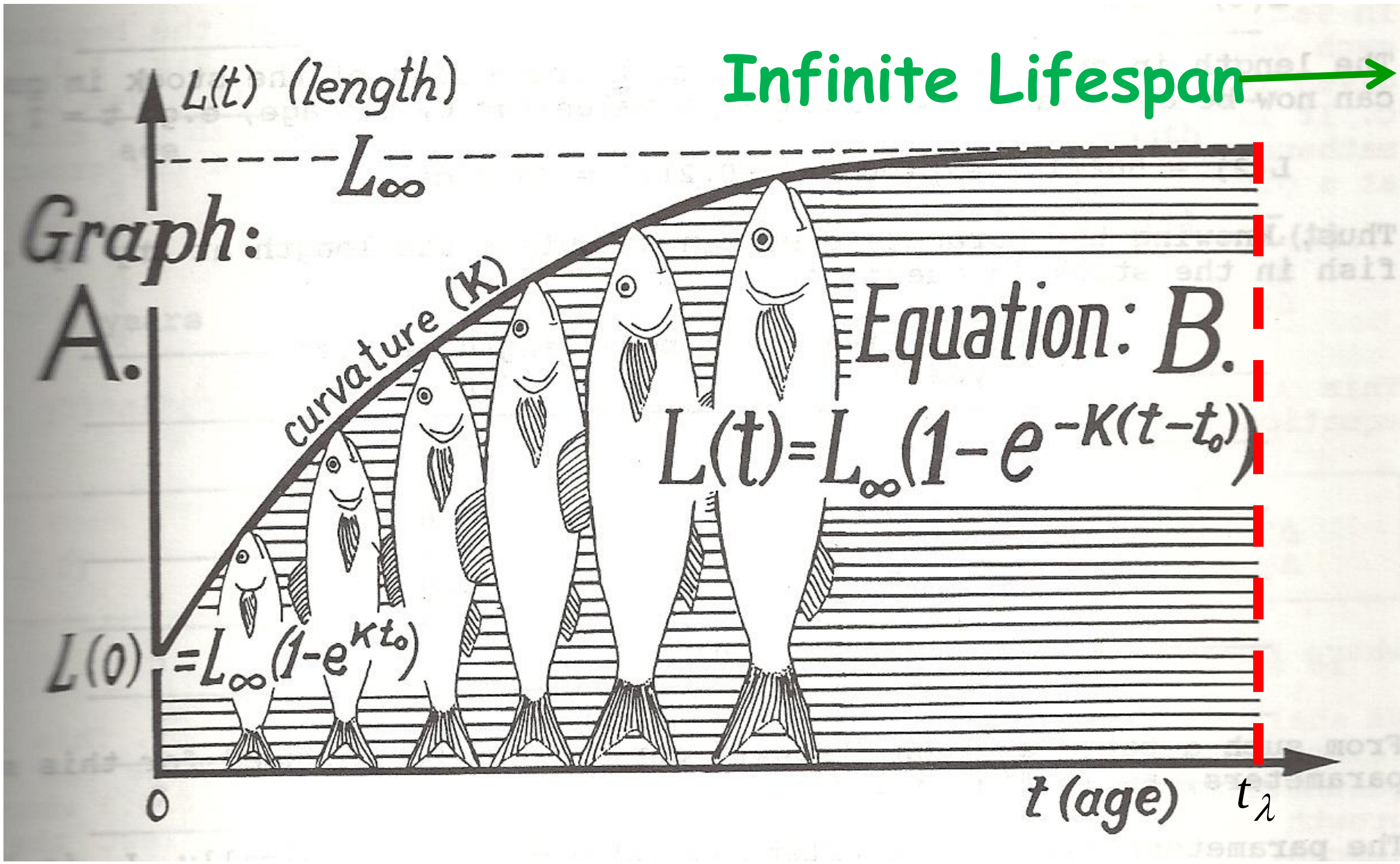


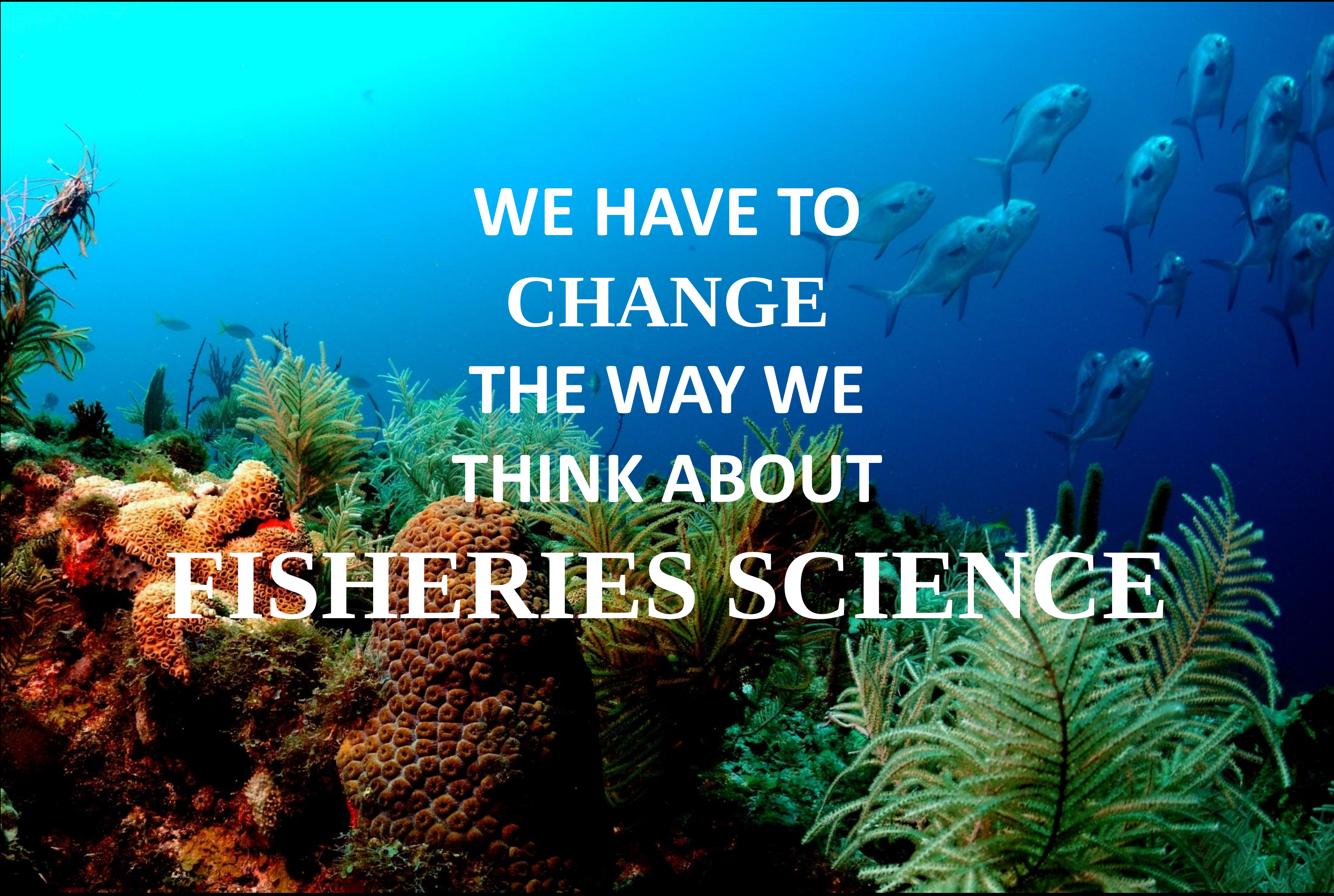




Size and age from growth curves

$$L_t = L_\infty (1 - e^{-k(t - t_0)})$$




WE HAVE TO
CHANGE
THE WAY WE
THINK ABOUT
FISHERIES SCIENCE

Multispecies Population Conservation Equations

(1) Abundance (numbers-at-age a for cohort *i*

$$\frac{dN_i}{dt} = \left(\frac{\partial N_i}{\partial a} da + \frac{\partial N_i}{\partial t} dt \right)$$

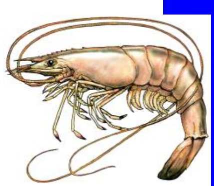
+ advection + diffusion + taxis/kinesis

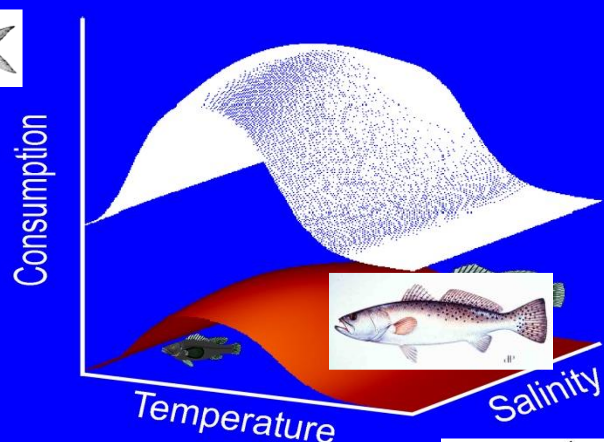
Predator-Prey Reaction Kinetics

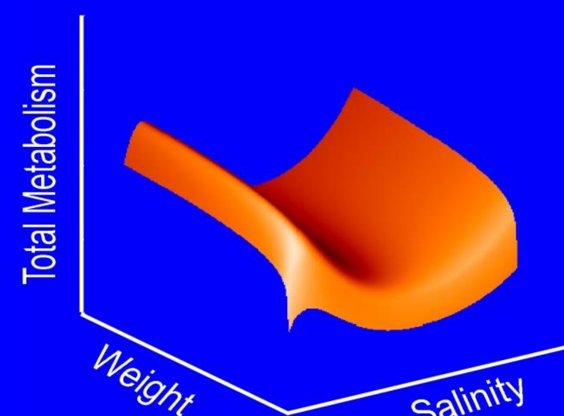
Drift, Density-dependent Competition & Environmental "habitat" Preferences

(2) Individual Weight-at-age (to population biomass)

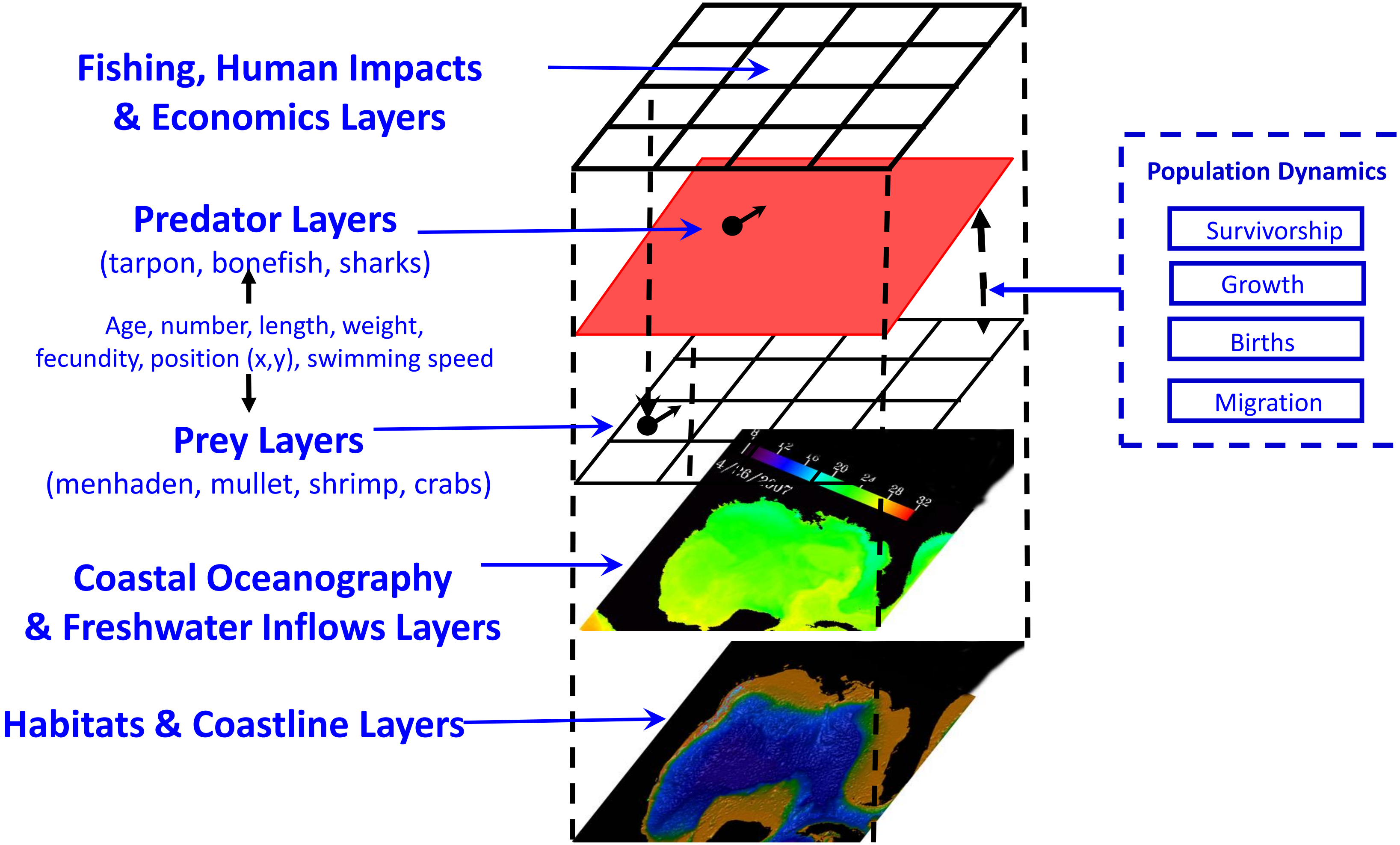
<u>Bioenergetics:</u> dW/dt = anabolism - catabolism







21st Century Scientific Challenge to Achieve Fishery Sustainability



Evolution of Thinking about Fisheries Ecosystems

Traditional Stock Assessment Models → **Spatial-Dynamic Multispecies Models**

Sustainability Threat
Directed Fishing on Single Target Species

Management Controls, Single Species
Gear/Size, Effort/Bag Limit Restrictions
Seasonal Closures

Sustainability Threats
Directed Fishing on Single Target Species
Directed Fishing on Multiple Species
Indirect Fishing on Key Prey Species
Alterations to Habitat/Water Quality
Climate Changes & Climate Variability

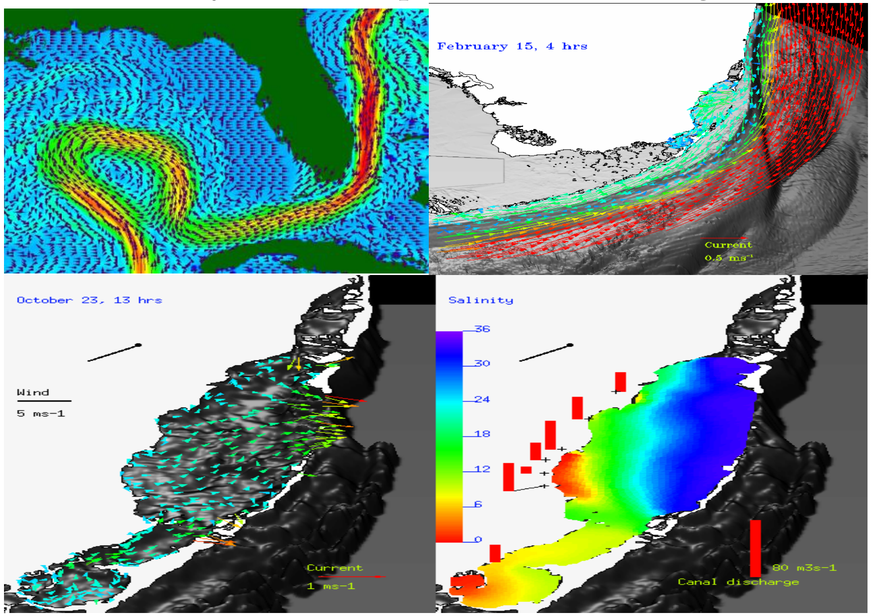
Management Controls, Multiple Target/Prey Species
Gear/Size, Effort/Bag Limit Restrictions
Seasonal Closures
Spatial Zoning, MPAs
Environmental Controls:
- Freshwater Inflows
- Land-based Sources of Pollution, Nutrients
- Coastal Development
- Dredging, Beach Renourishment

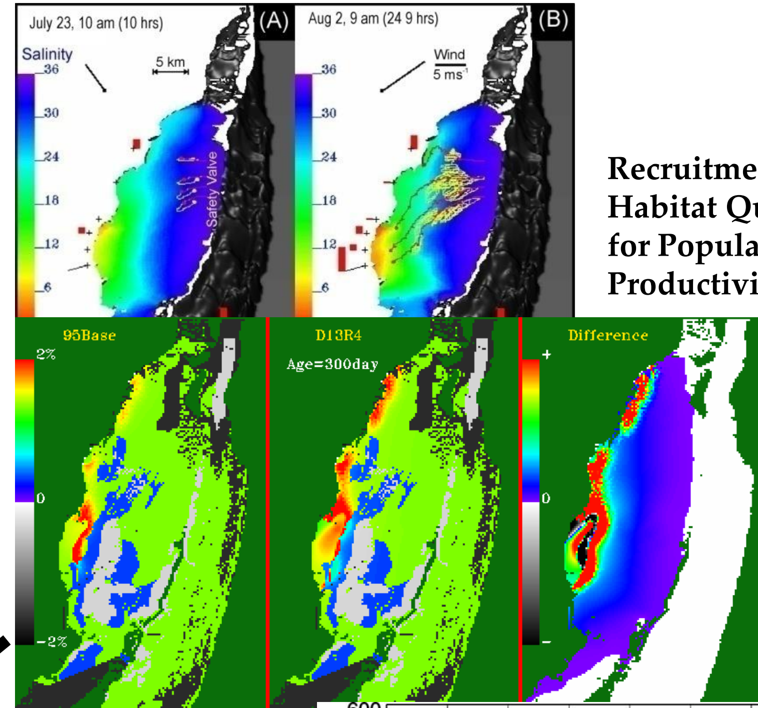
Longer-Term Management Strategies for Anticipated Climate Changes

Requires greater Agency interaction and cooperation!

Climate Changes and Fisheries Productivity

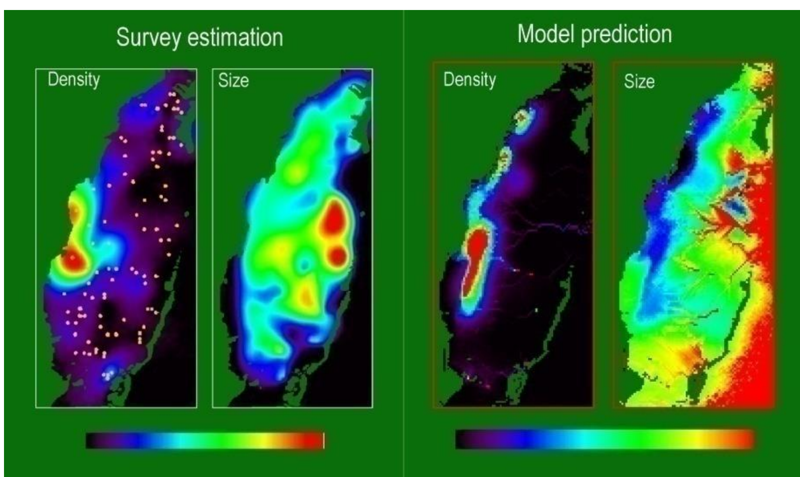
Physical Atmospheric-Ocean Forcing



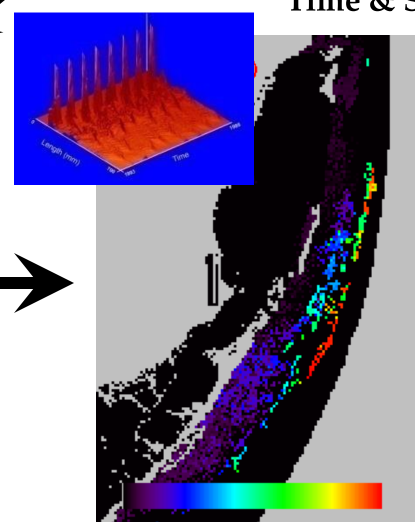


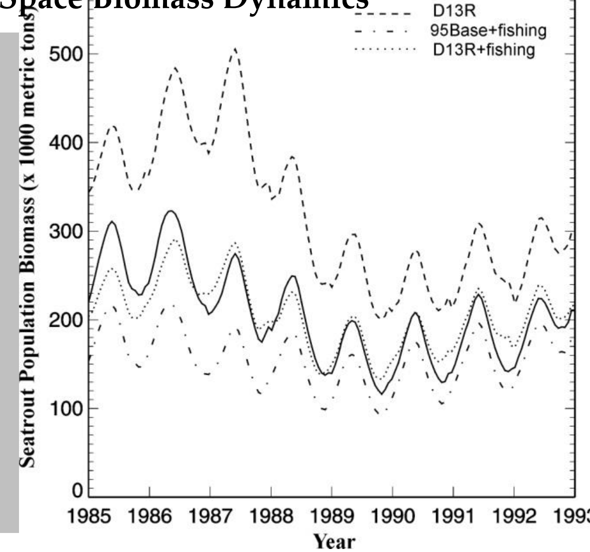
Recruitment & Habitat Quality for Population Productivity

Spatial Population Abundance & Size Structure



Time & Space Biomass Dynamics



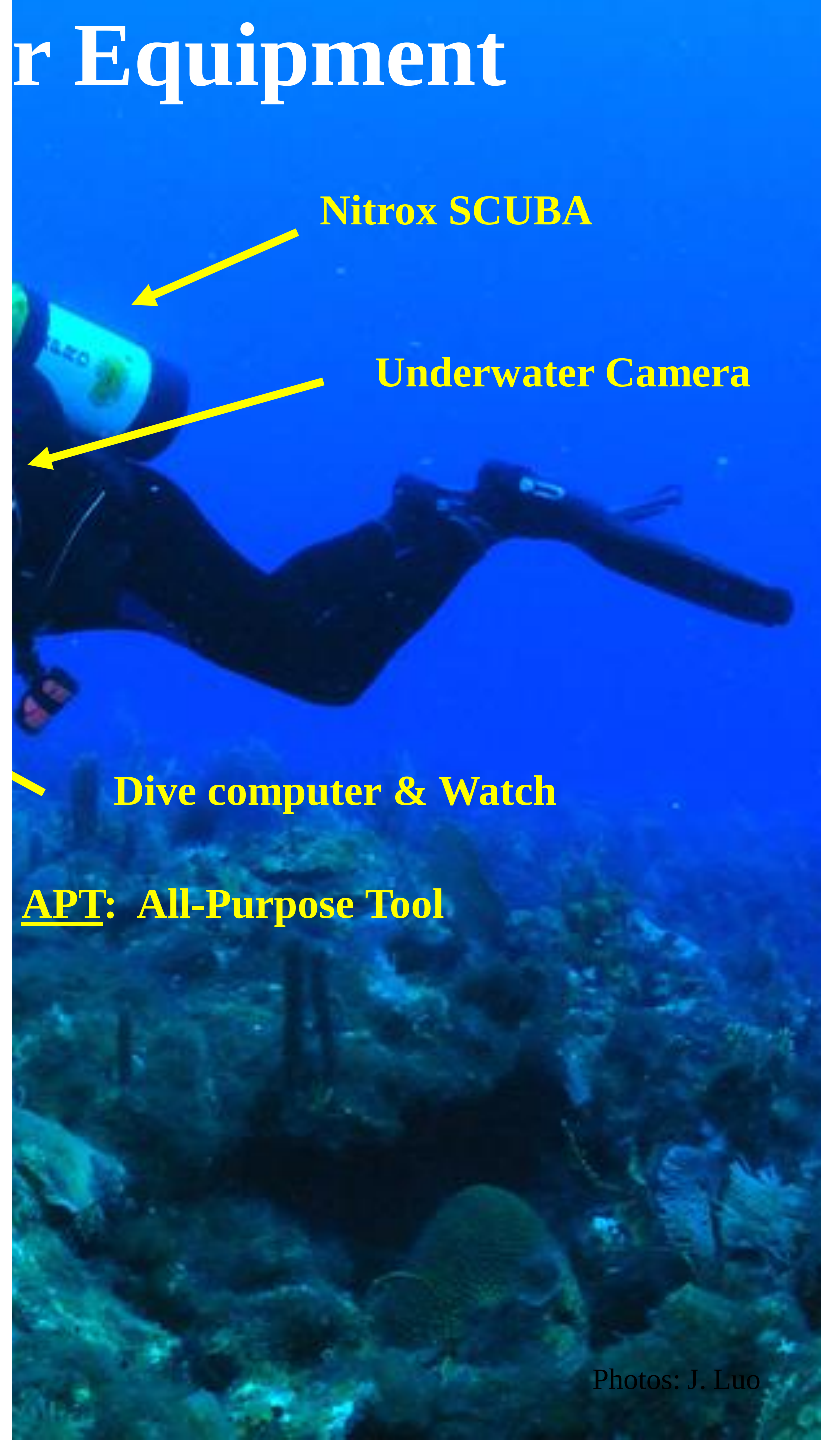


National Park Service
U.S. Department of the Interior

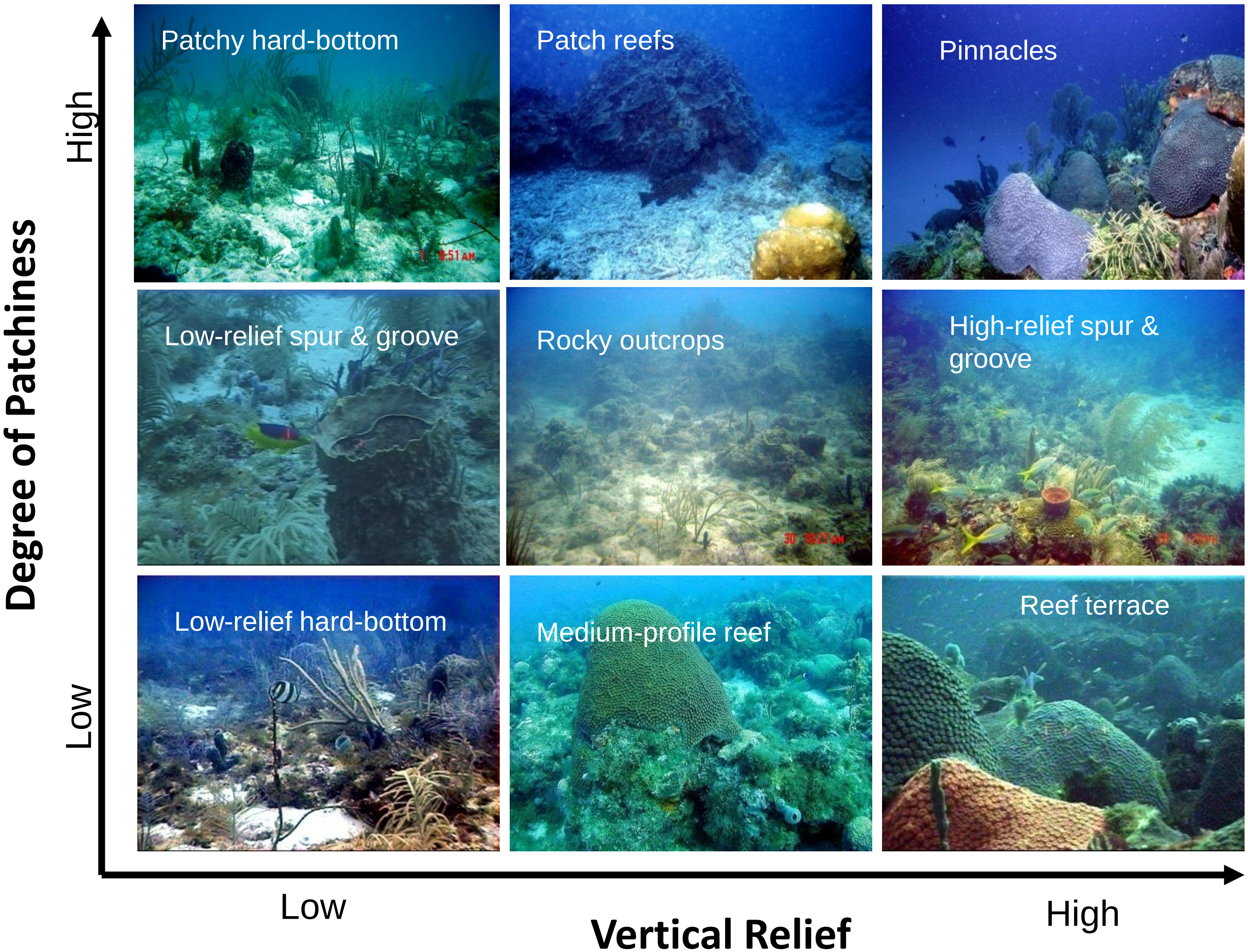
Natural Resource Program Center

A Cooperative Multi-agency Reef Fish Monitoring Protocol for the Florida Keys Coral Reef Ecosystem

Natural Resource Report NPS/SFCN/NRR—2009/XXX (FOR PEER REVIEW)

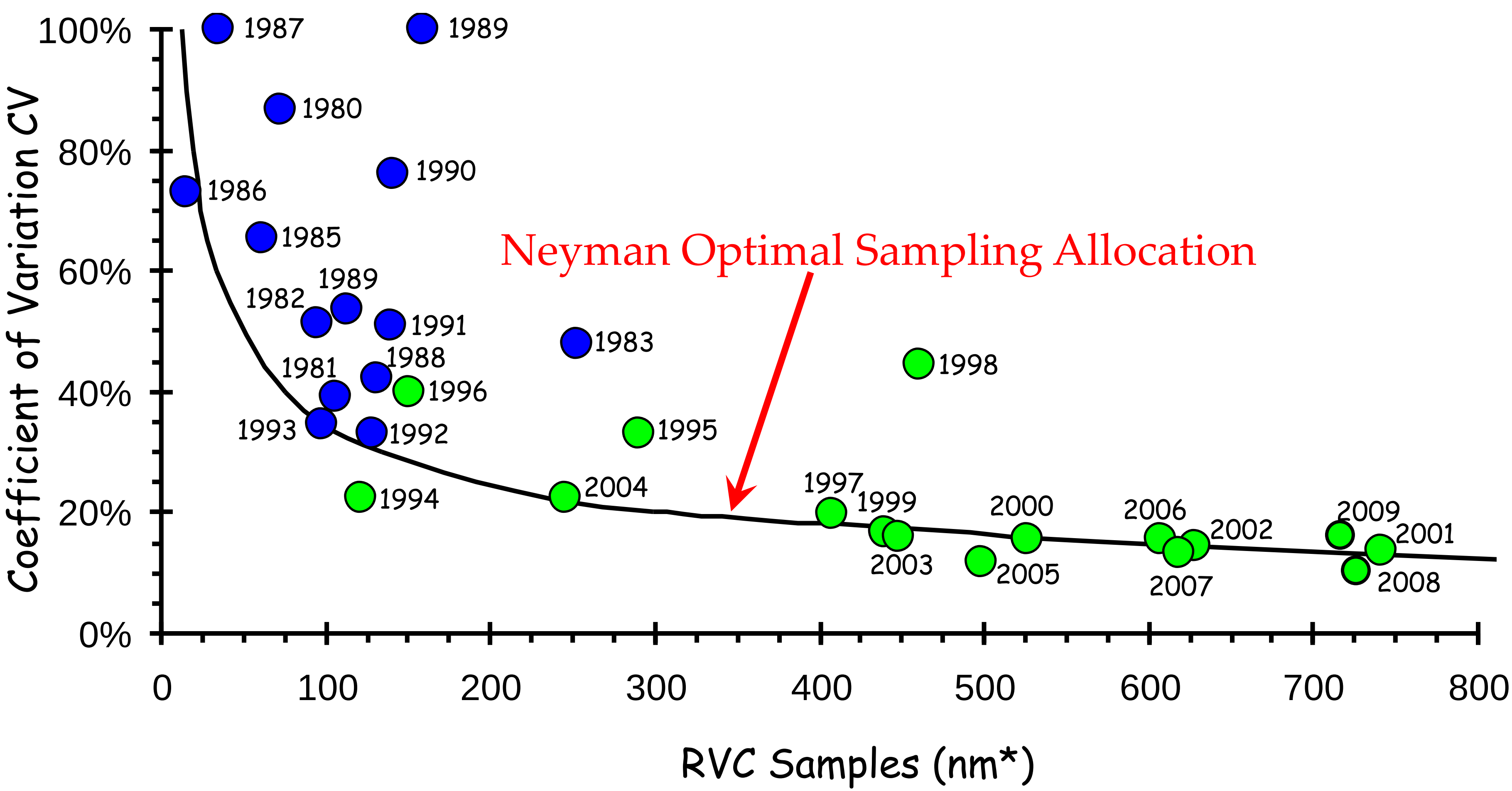


Linking Reef-Fish Spatial Abundance & Benthic Habitats



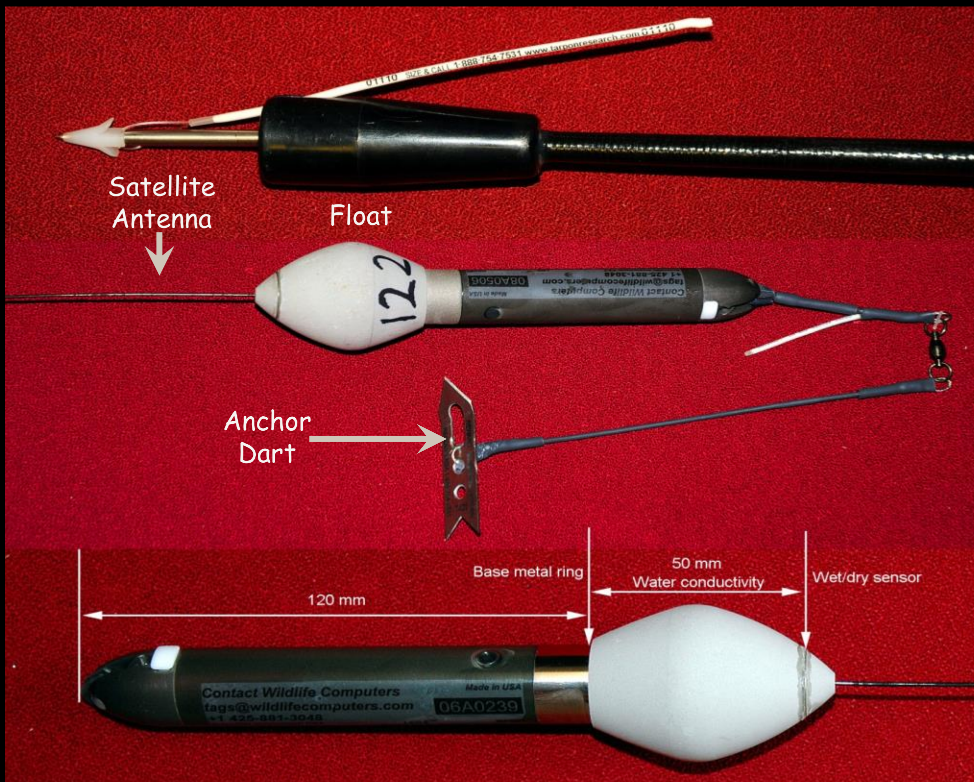
Smith, Ault, Bohnsack et al. 2011. *Fisheries Research*
Franklin, Ault, Smith, Luo, Bohnsack et al. 2003. *Marine Geodesy*

Florida Keys
Sampling Design Efficiency 1979-2010



Smith, Ault et al. 2011. Fisheries Research 109(1): 25-41.

Cost-effective use of satellite-based technologies to study migrations, habitat use and spawning areas



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Vertical movement rates and habitat use of Atlantic tarpon

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FIELD & STREAM

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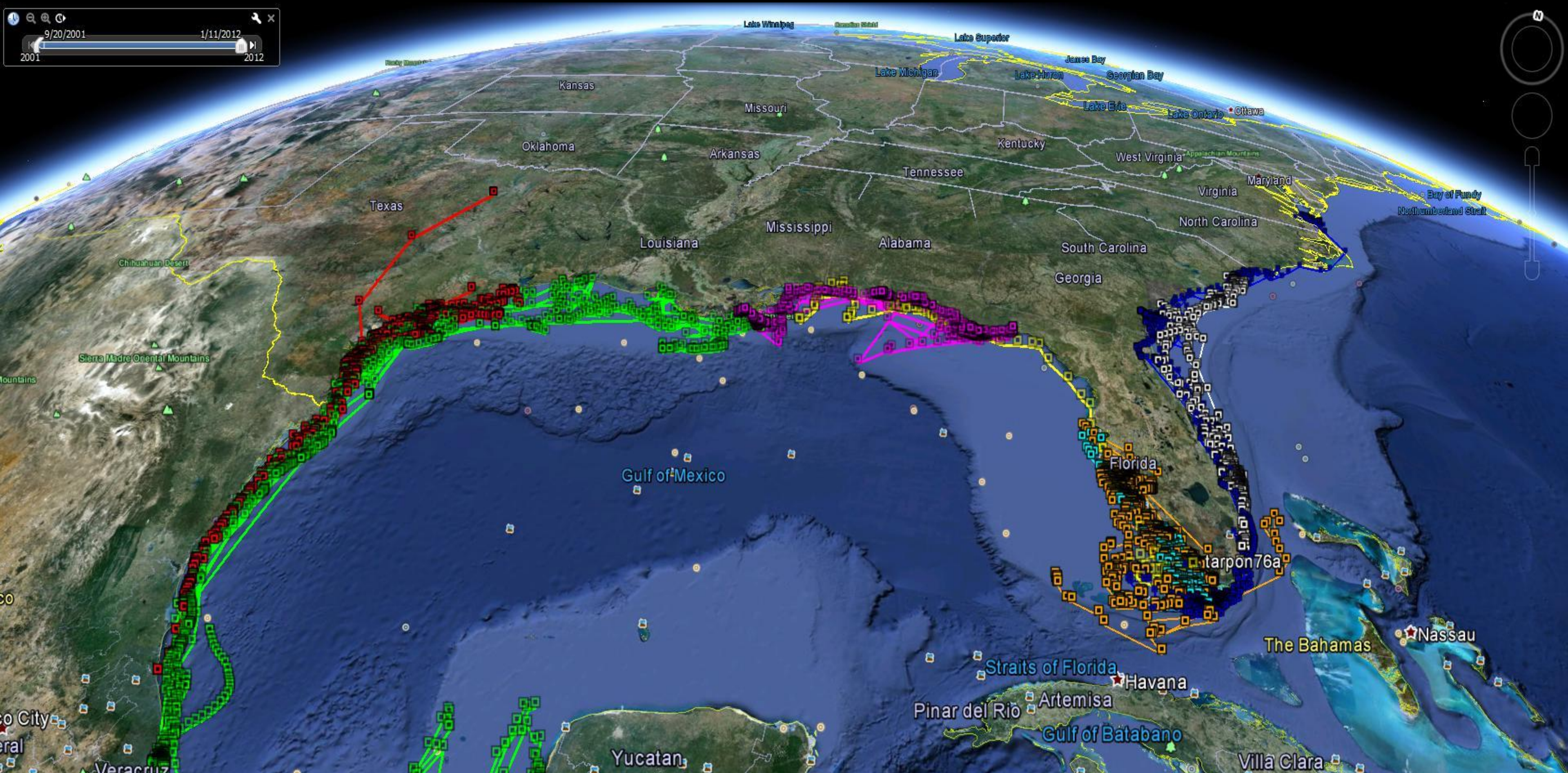
July 12, 2006

Heroes of Conservation Photo Gallery

Photo: Dr. Jerald S. Ault

The Bonefish and Tarpon Conservation Research crew from the University of Miami tag fish caught in a 2005 tarpon tournament in Veracruz, Mexico. An understanding of tarpon migration patterns and feeding habits is crucial to the fishery's offshore management. The group attached a Pop-up Archival Transmitting Tag to each fish behind its head.

Documented travels of the mighty Atlantic Tarpon



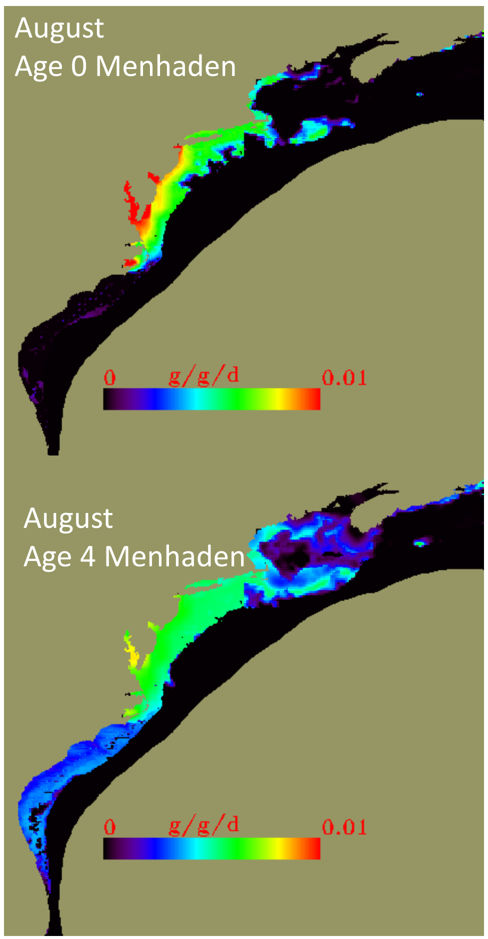
Migrations, ocean habitat use & spawning,

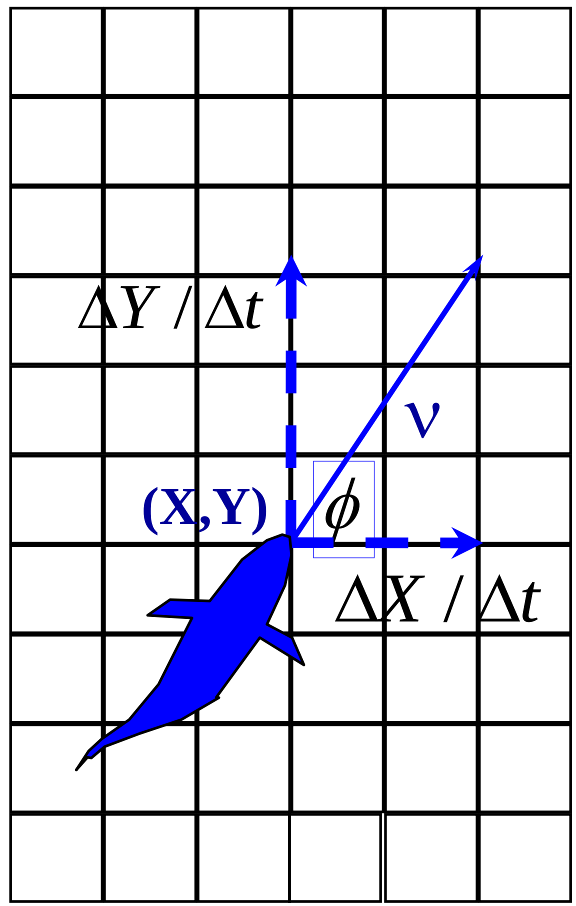
Transport and Movements of Predator & Prey

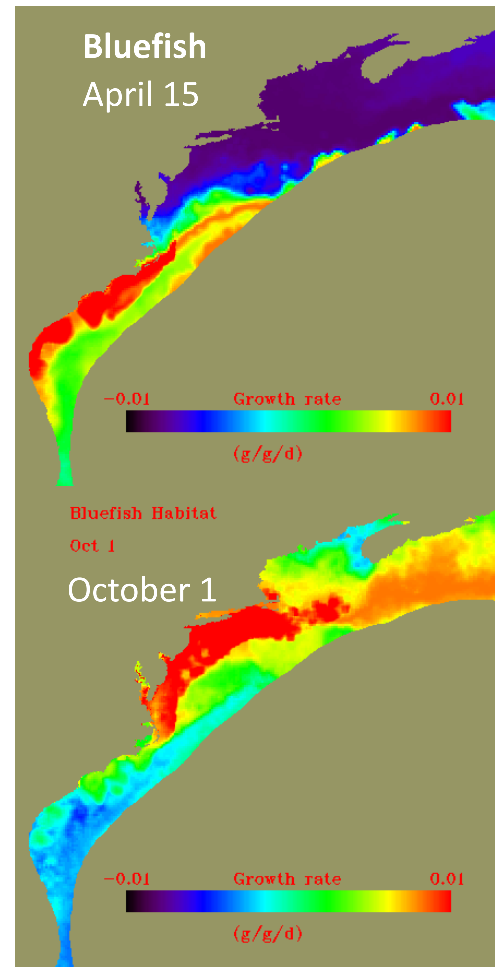
Factors affecting fish "*spatial growth rate potential*" $\frac{dW}{Wdt}$ components of "essential habitat".

$$X_b(\Omega) = \left(\tilde{V}(a,t) * \left[1 - e^{\phi \left(\frac{\Omega(t) - \Omega_{\max}}{\Omega_{\max}} \right)} \right] \right) * \cos(\theta_{\max} + \xi\pi)$$

$$Y_b(\Omega) = \left(\tilde{V}(a,t) * \left[1 - e^{\phi \left(\frac{\Omega(t) - \Omega_{\max}}{\Omega_{\max}} \right)} \right] \right) * \sin(\theta_{\max} + \xi\pi)$$



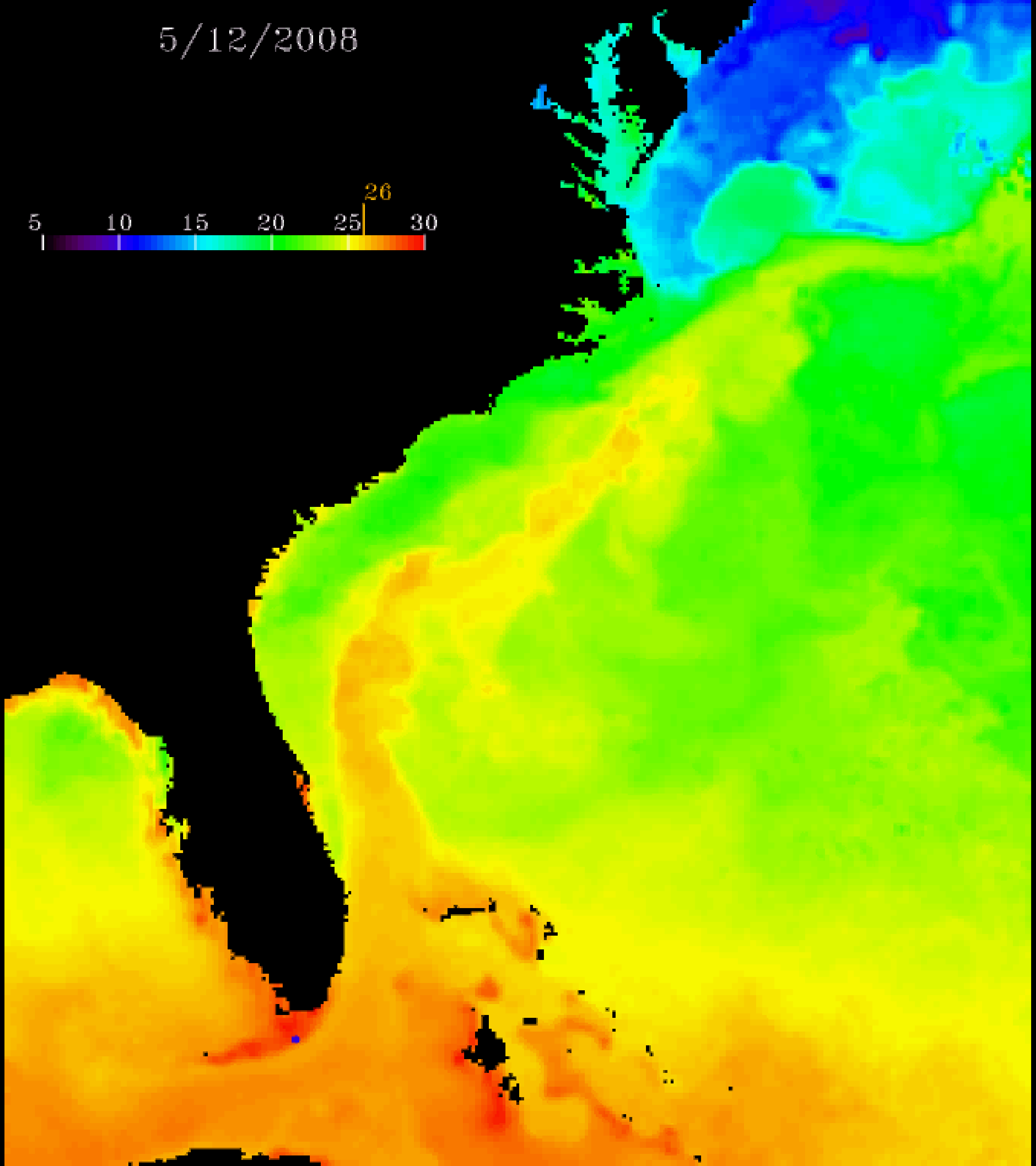




Orange is Optimal!

26°C (79°F)

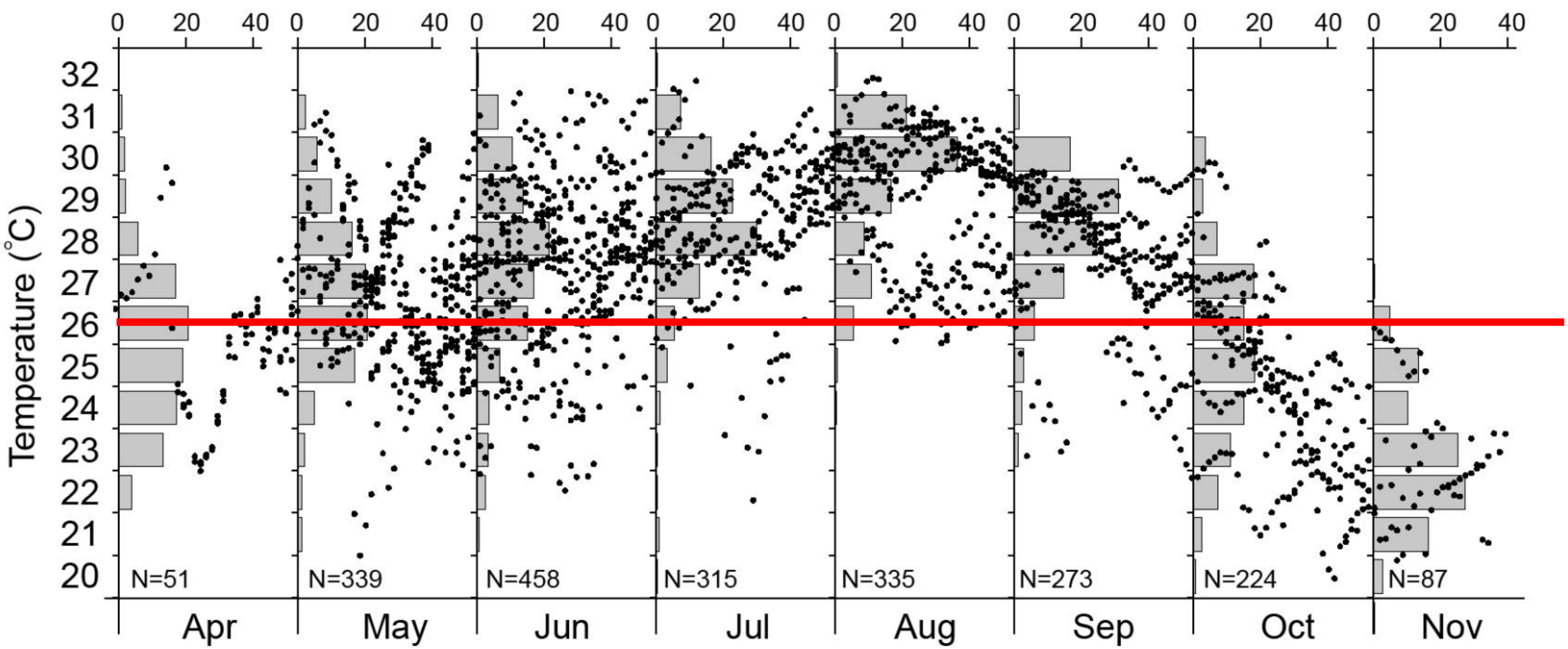
T116



Many fishes also like water temperature >26 ^{o}C!

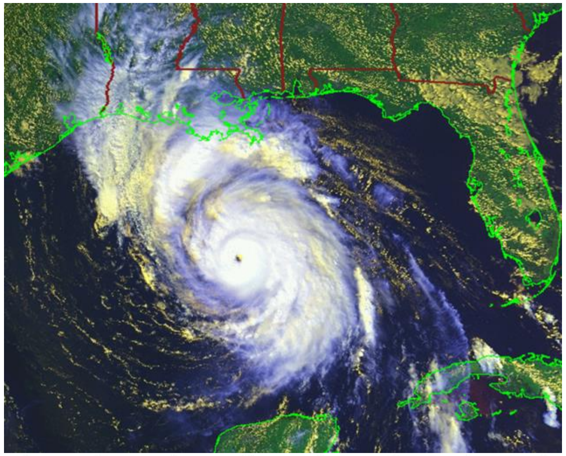
Water Temperature data from Tarpon satellite PAT-tags

Temperature frequency (%) distribution by month



Daily averages (dots) and monthly frequency distributions (bars).

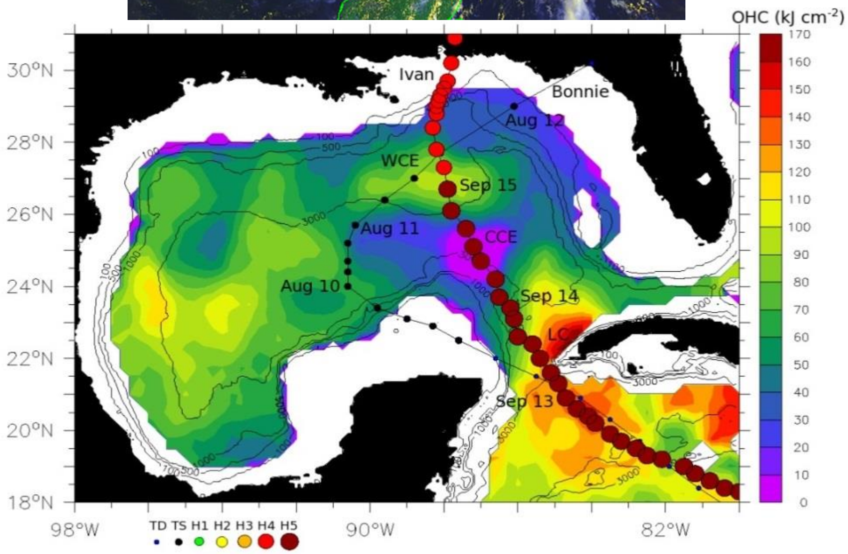
What is OHC & Who Cares?



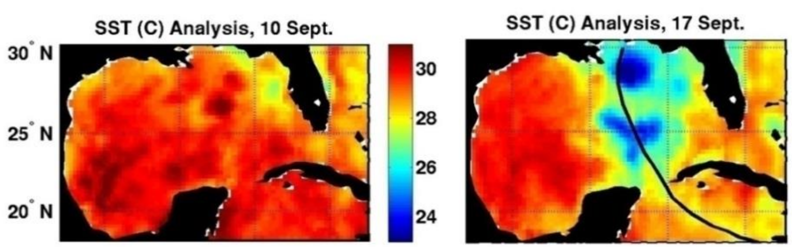
Ocean Heat Content (OHC)

"The integrated thermal energy from sea surface to the depth of the 26 ºC isotherm".

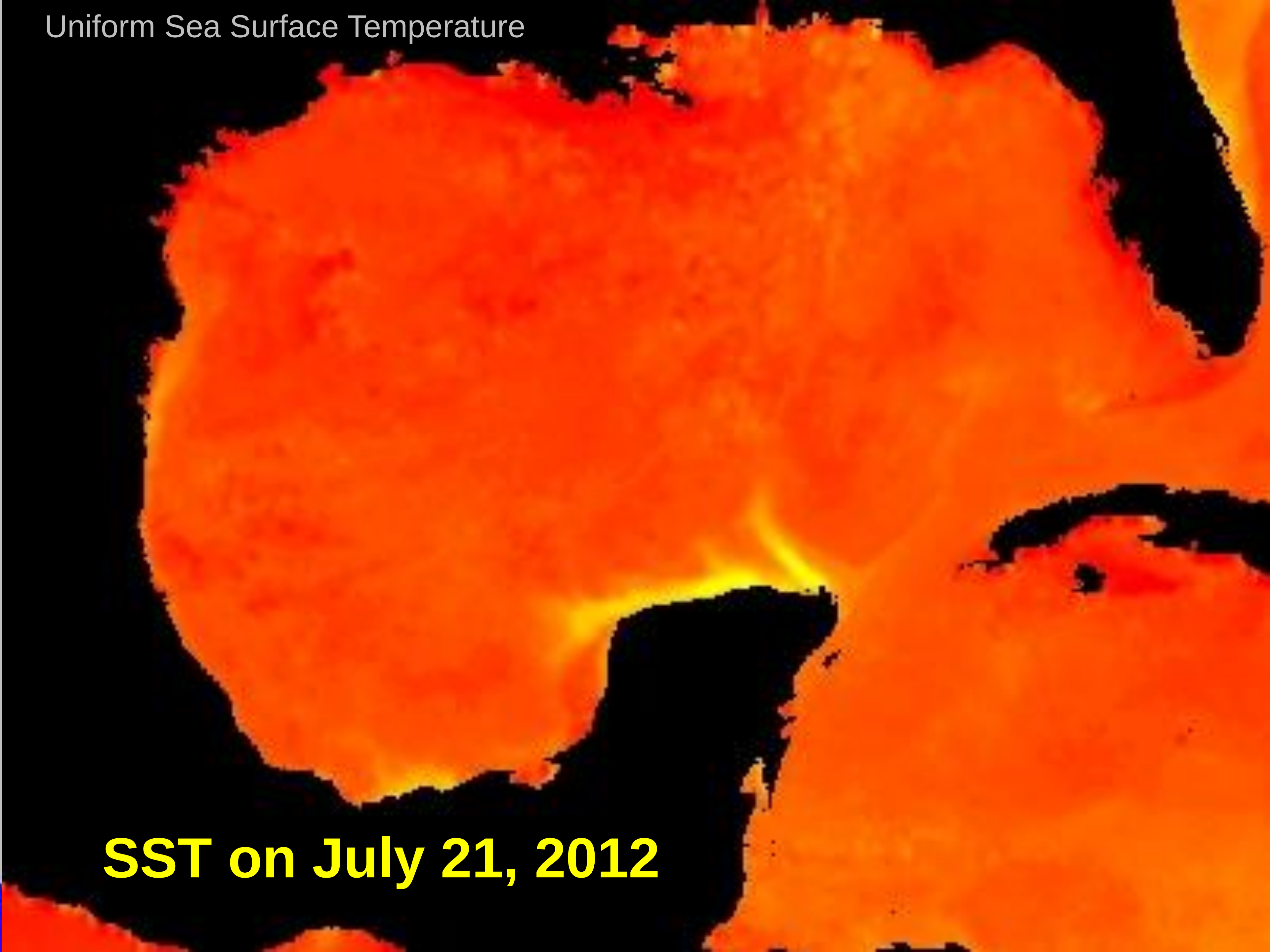
Tropical cyclones are a **BIG** deal!.



OHC during September 15, 2004.

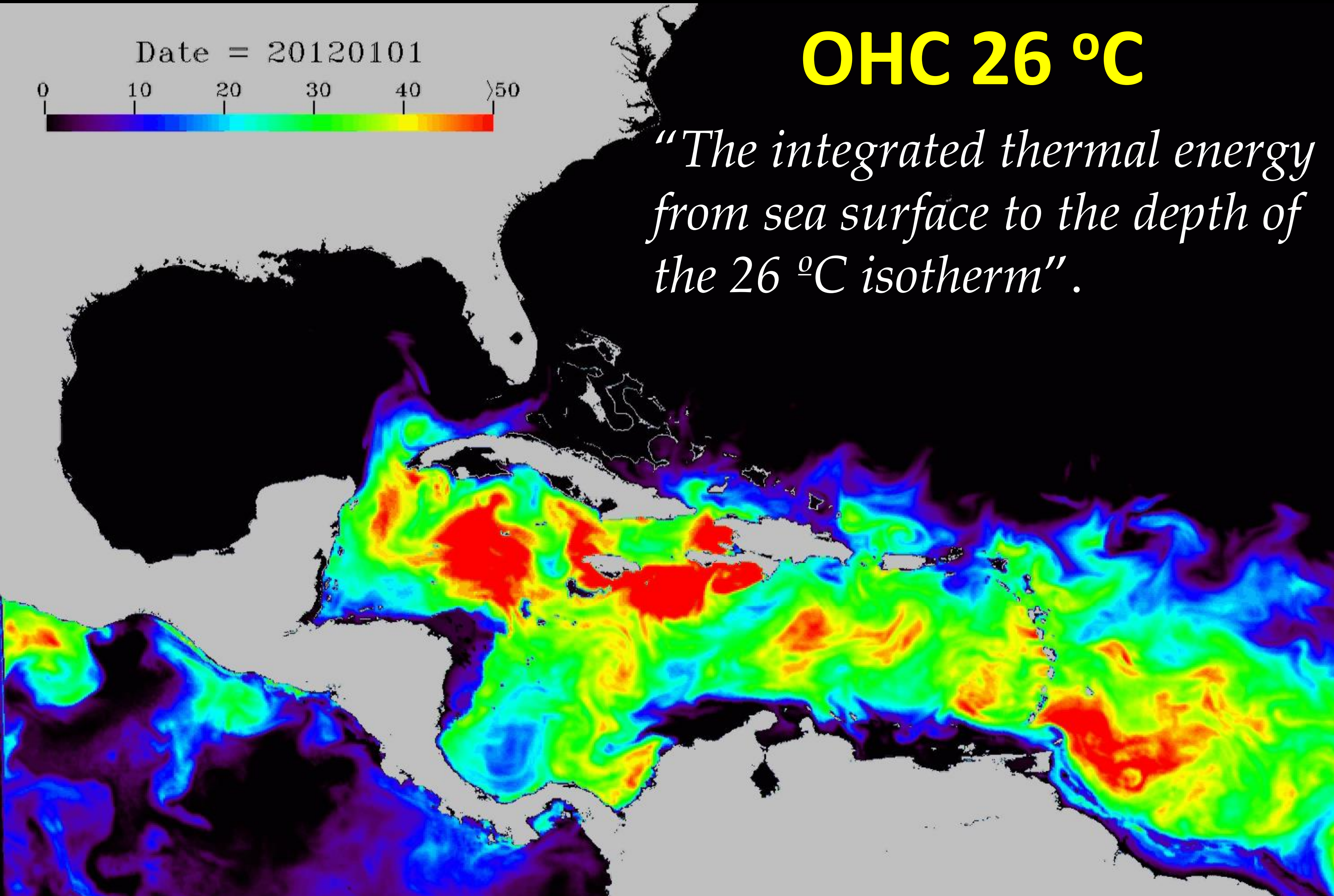


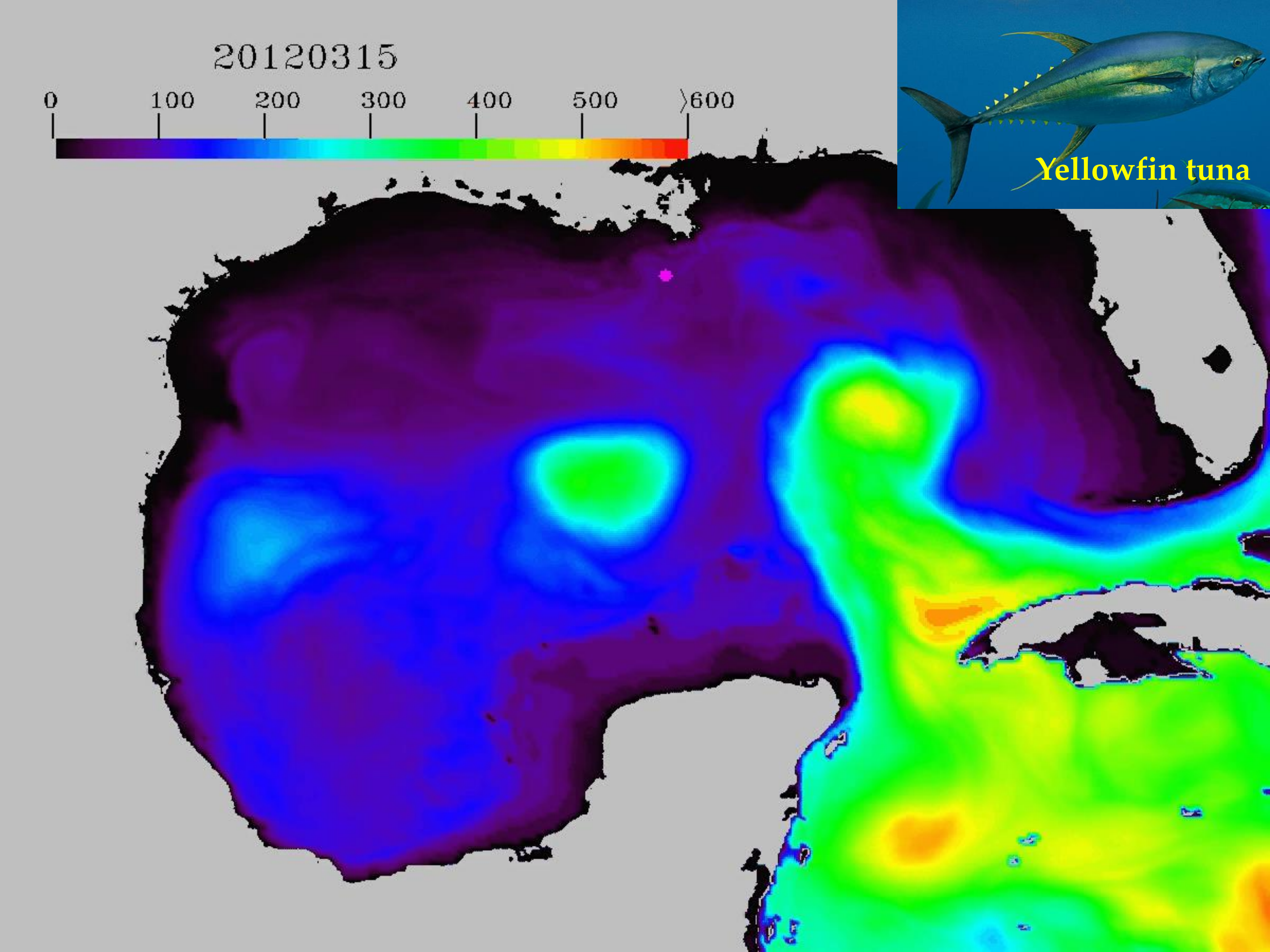
SST before (left) and after (right) the passage of Hurricane Ivan (2004) showing upper ocean cooling.

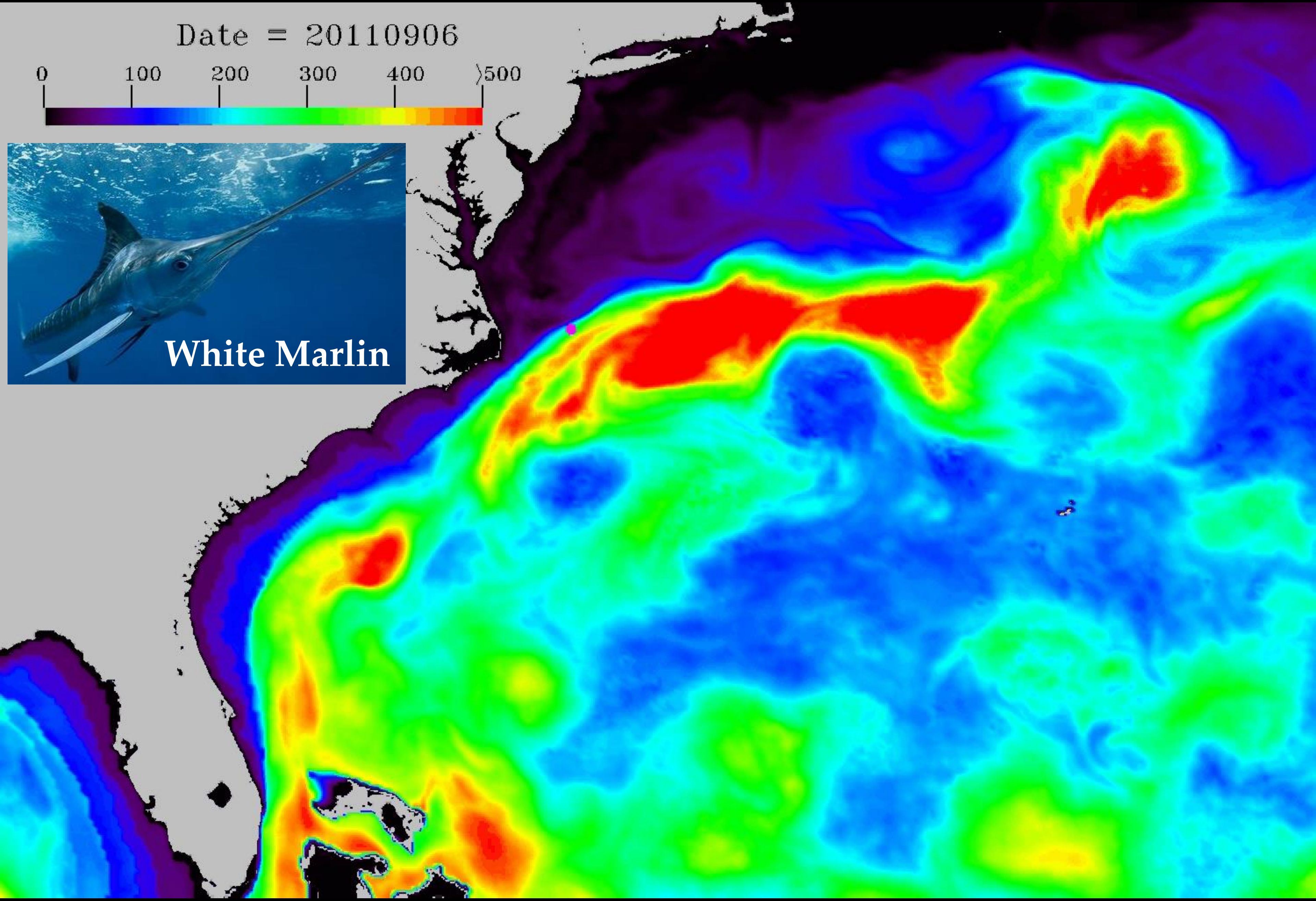

Uniform Sea Surface Temperature
SST on July 21, 2012

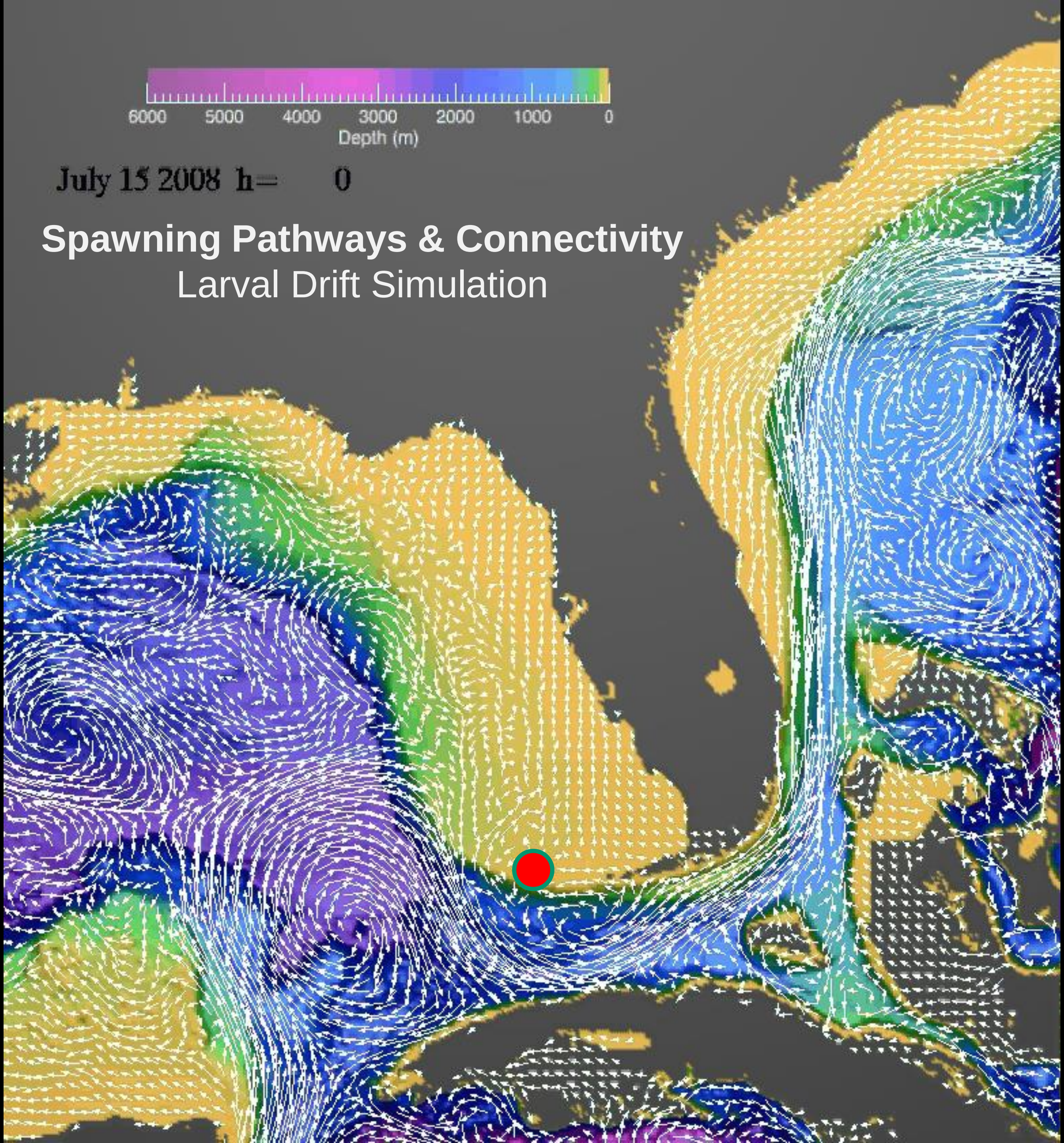
OHC 26 ºC

"The integrated thermal energy from sea surface to the depth of the 26 ºC isotherm".

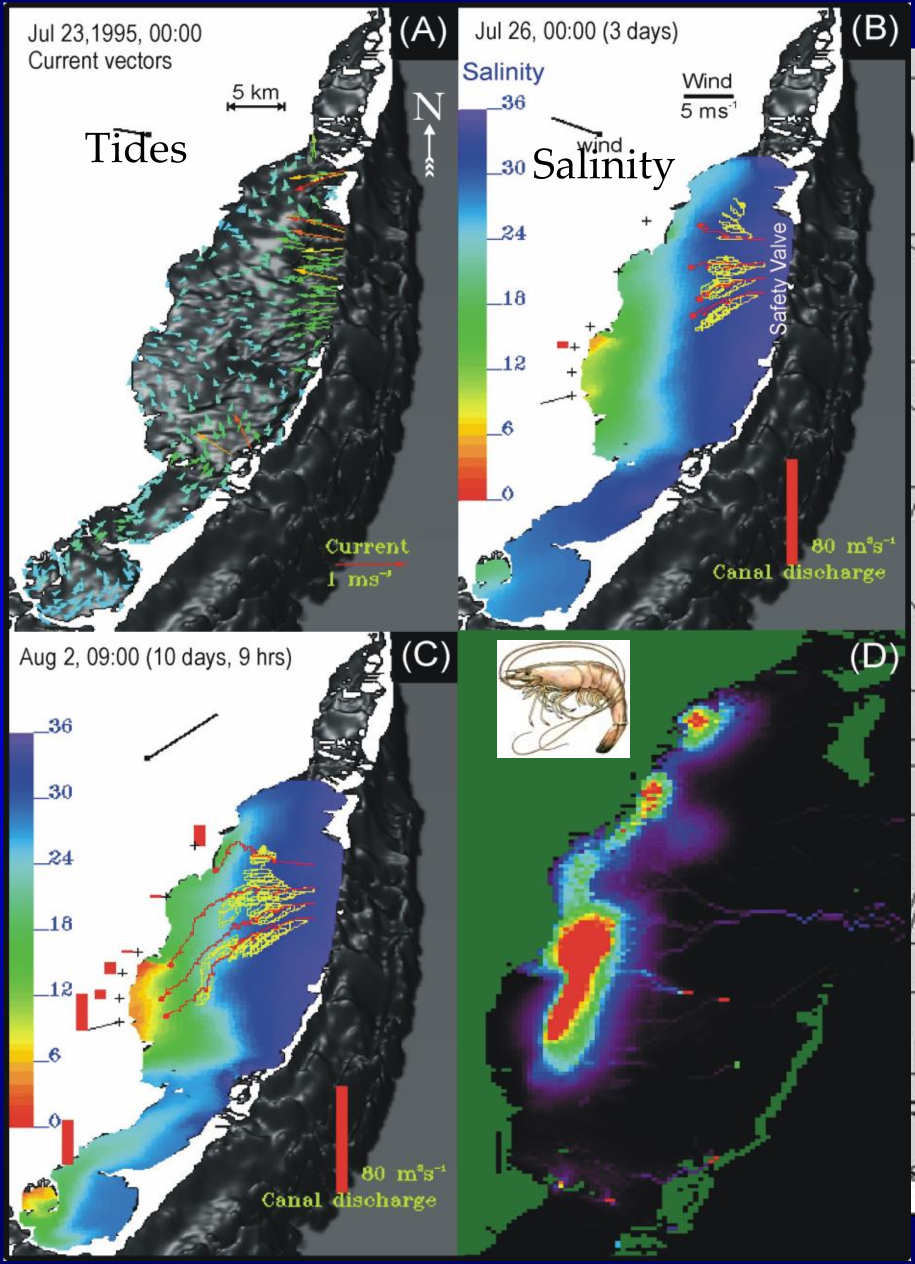


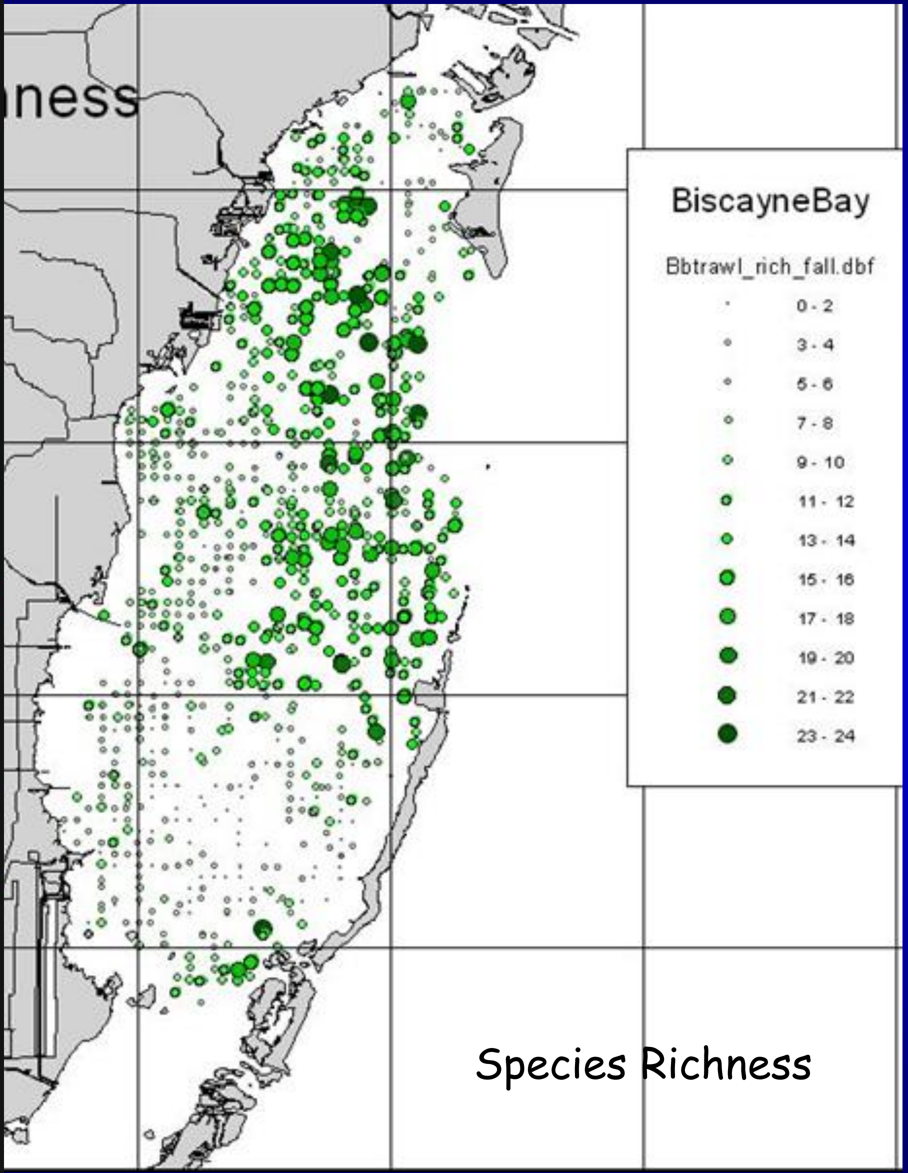

20120315
0
100
200
300
400
500
>600
Yellowfin tuna


Date = 20110906
0
100
200
300
400
>500
White Marlin

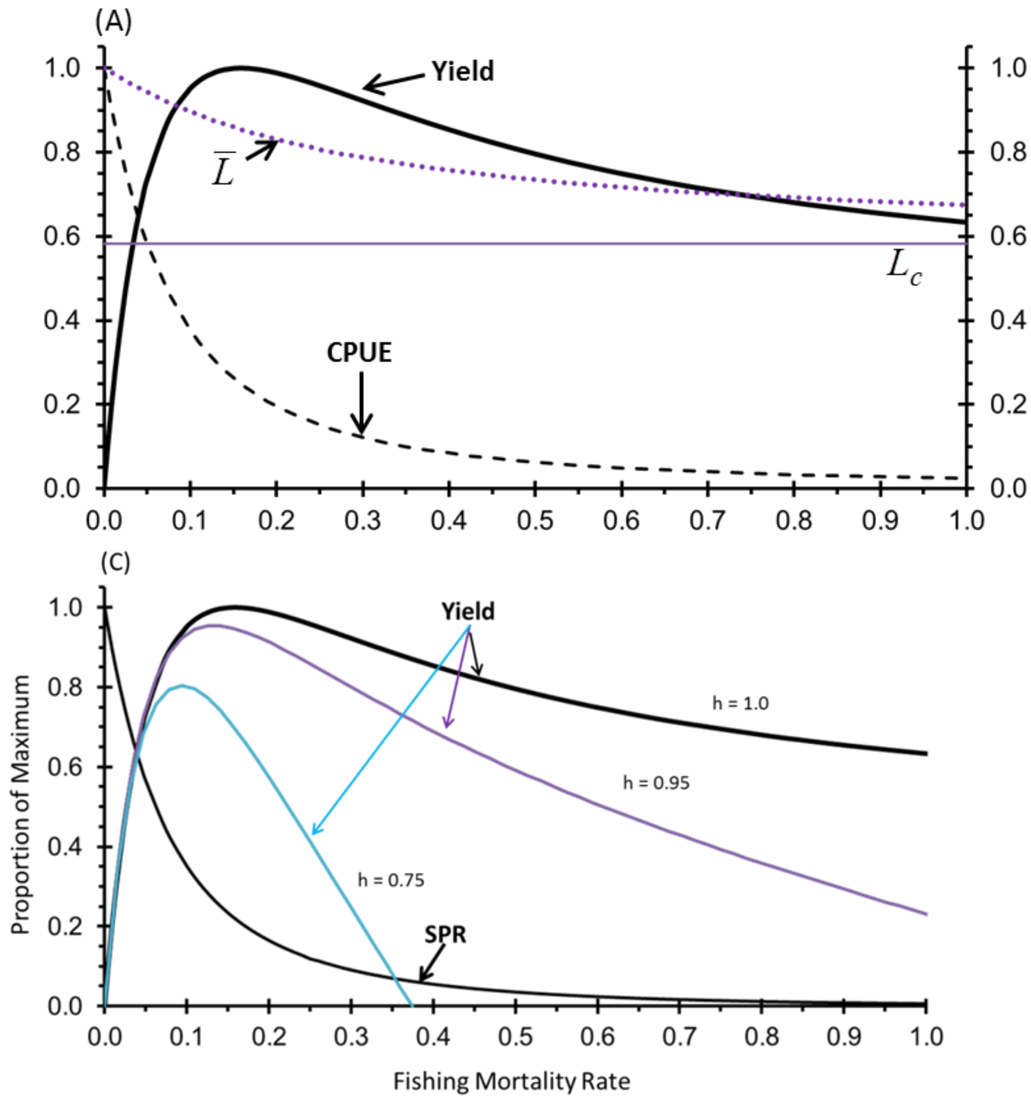

6000 5000 4000 3000 2000 1000 0
Depth (m)
July 15 2008 h= 0
Spawning Pathways & Connectivity
Larval Drift Simulation

Coastal Bays to the Coral Reefs

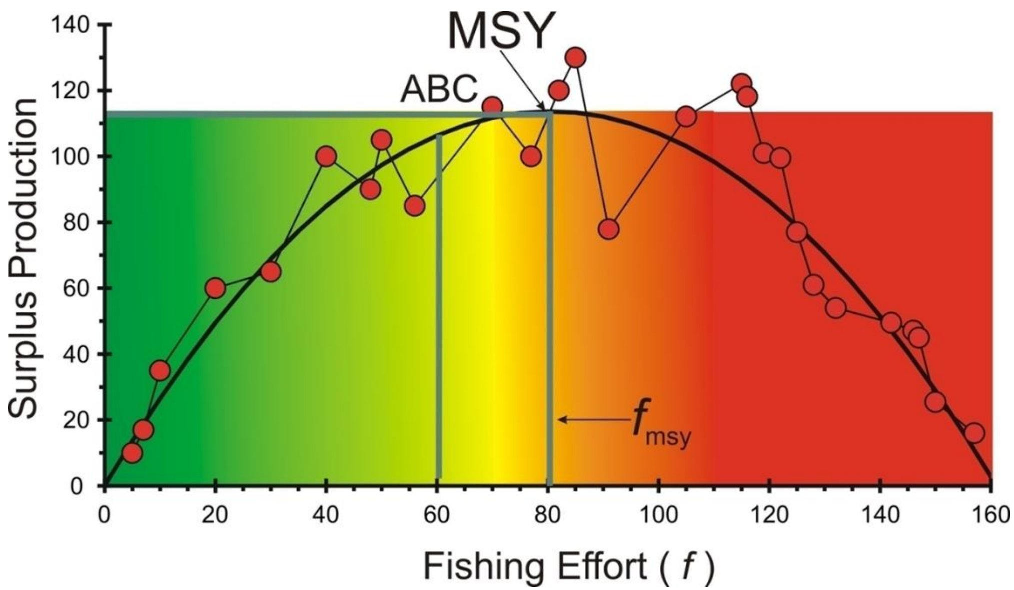


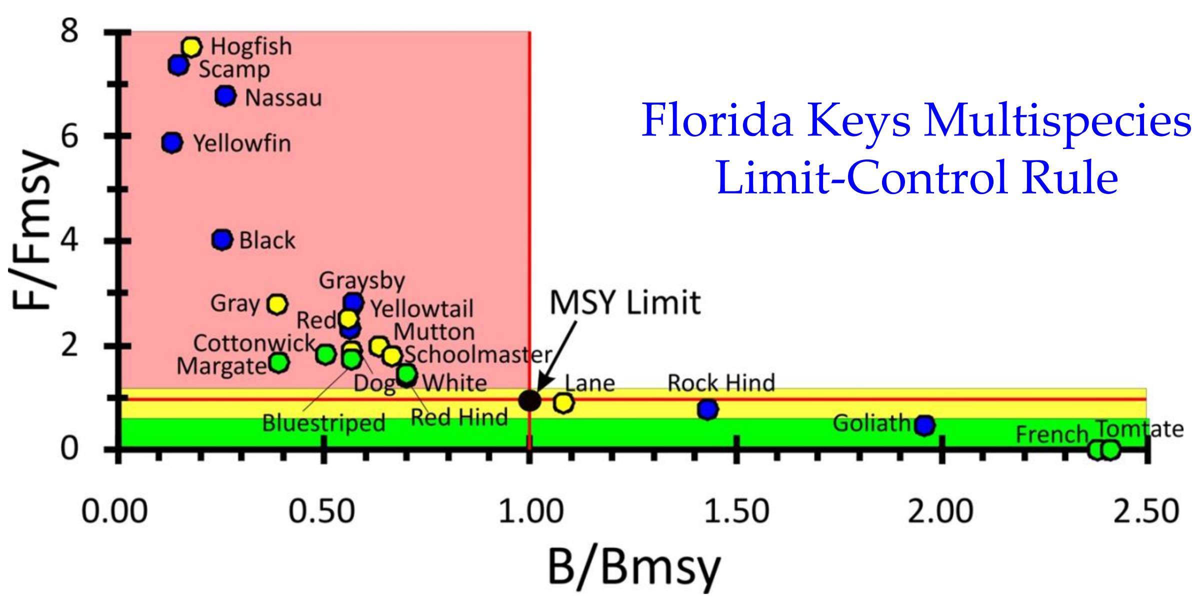


Density-independence to Density-dependence



Fisheries Sustainability Relationships





Optimal Design of Marine Reserves

OBJECTIVE FUNCTION

$$Min\left\{\mu_q^+ q^+ + \sum_{s\in S}\left(\mu_s^+ p_s^+ + \mu_s^- p_s^-\right) + \left(\mu_f^+ f^+ + \mu_f^- f^-\right) + \left(\mu_c^+ c^+ + \mu_c^- c^-\right) + \left(\mu_a^+ a^+ + \mu_a^- a^-\right) + \sum_{r\in R}\left(\mu_{ar}^+ a_r^+ + \mu_{ar}^- a_r^-\right)\right\}$$

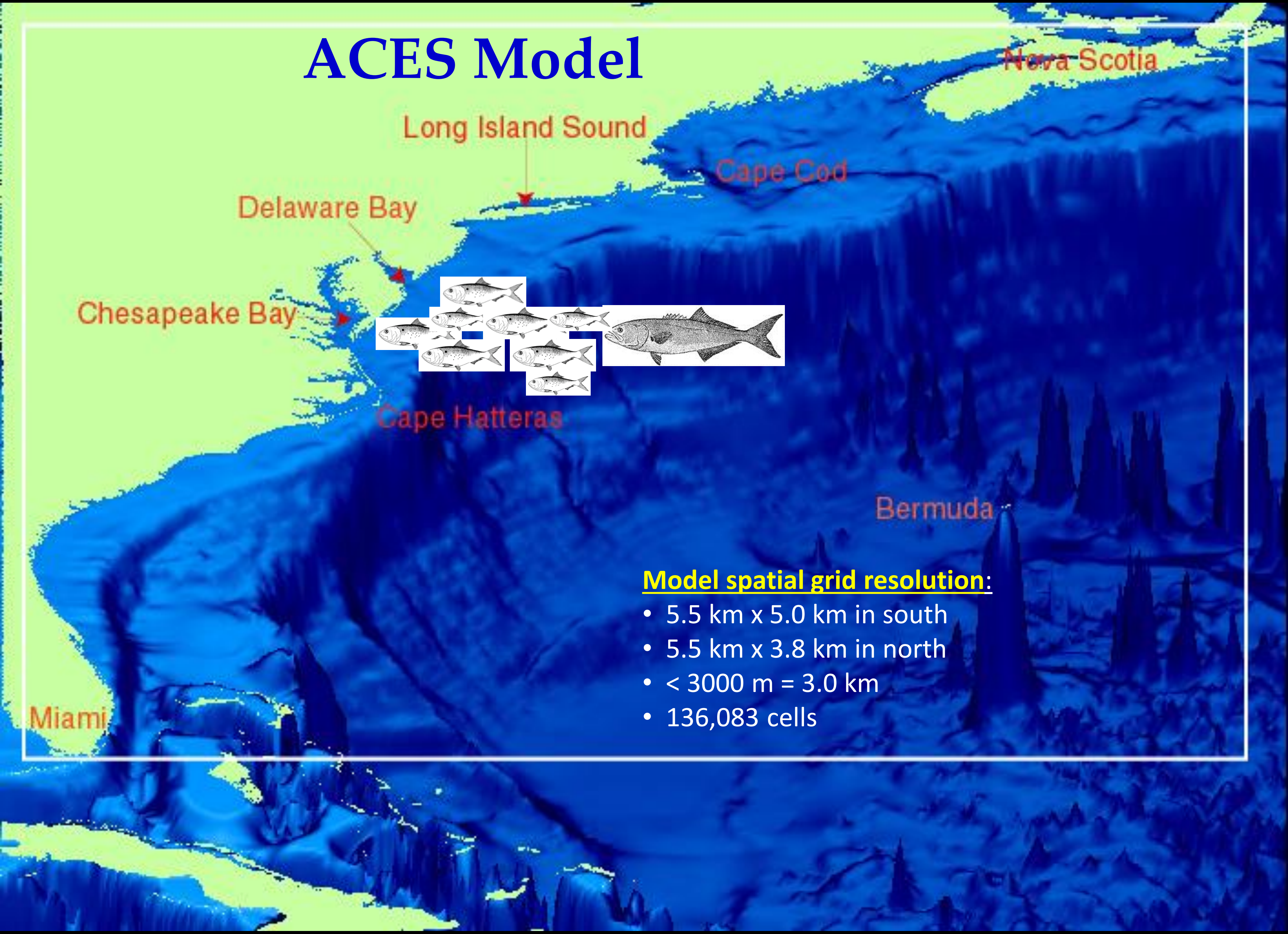
Reserve shape	SPR over all species	fishing effort	Reef area	Total Reserve area	Regional Reserve area

CONSTRAINTS -- SUBJECT TO:

(C1) Reserves non-overlapping
(C2) Pre-specified number of reserves
(C3) Fixed proportion of SPR protected
(C4) Maximum number of fishing vessels displaced by reserves
(C5) Target area of coral reef area protected
(C6) Target total area protected
(C7) Distribution of reserves among regions of ecosystem
(C8) Each reserve contiguous, compact, and desirably shaped

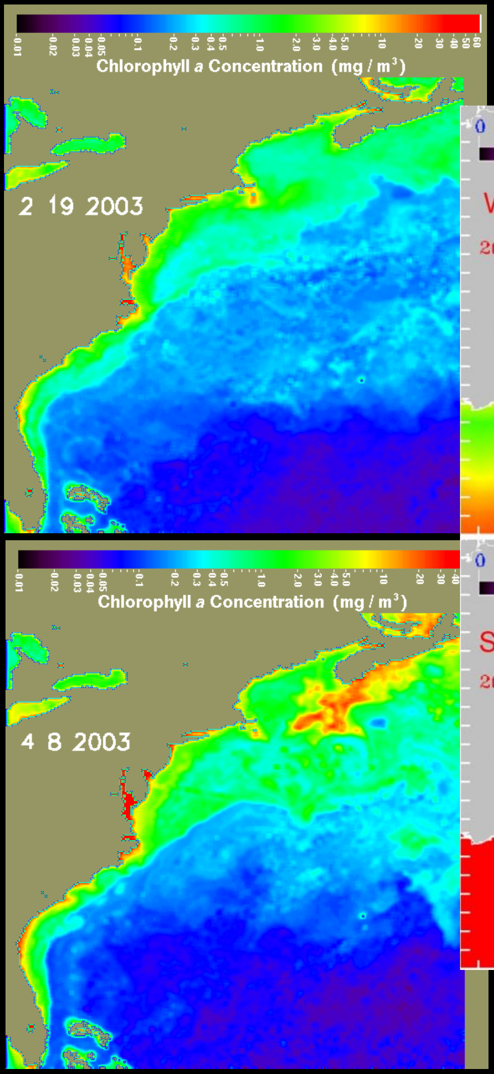
Meester, Mehrotra, Ault and Baker. 2004. Management Science 50: 1031-1043

ACES Model

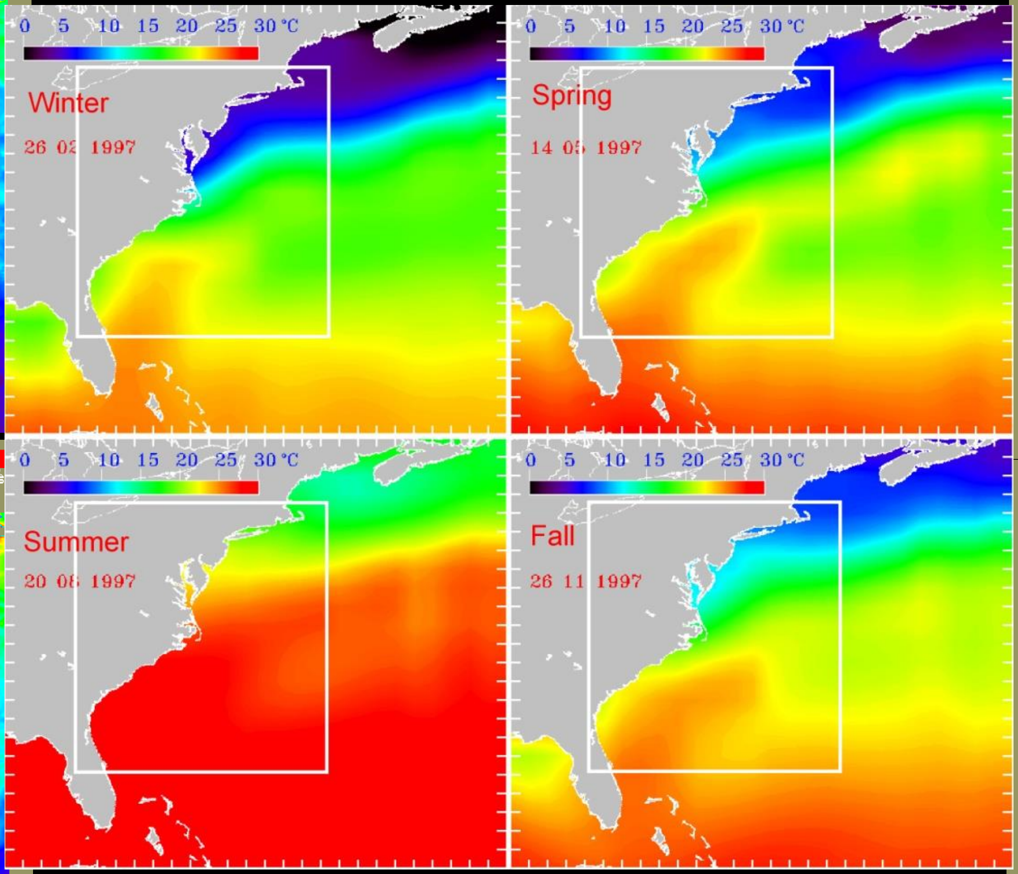


Model spatial grid resolution:
- 5.5 km x 5.0 km in south
- 5.5 km x 3.8 km in north
- < 3000 m = 3.0 km
- 136,083 cells

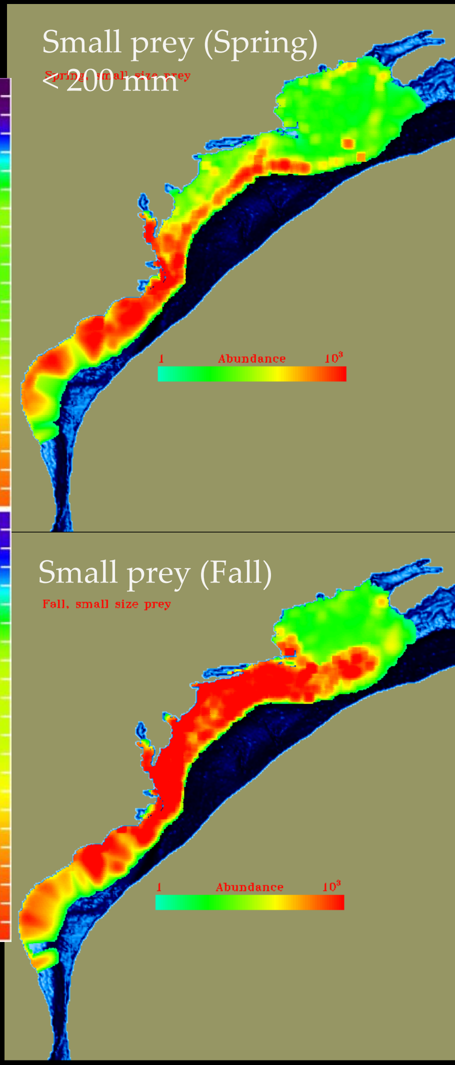
Chlorophyll a



Sea Surface Temperature



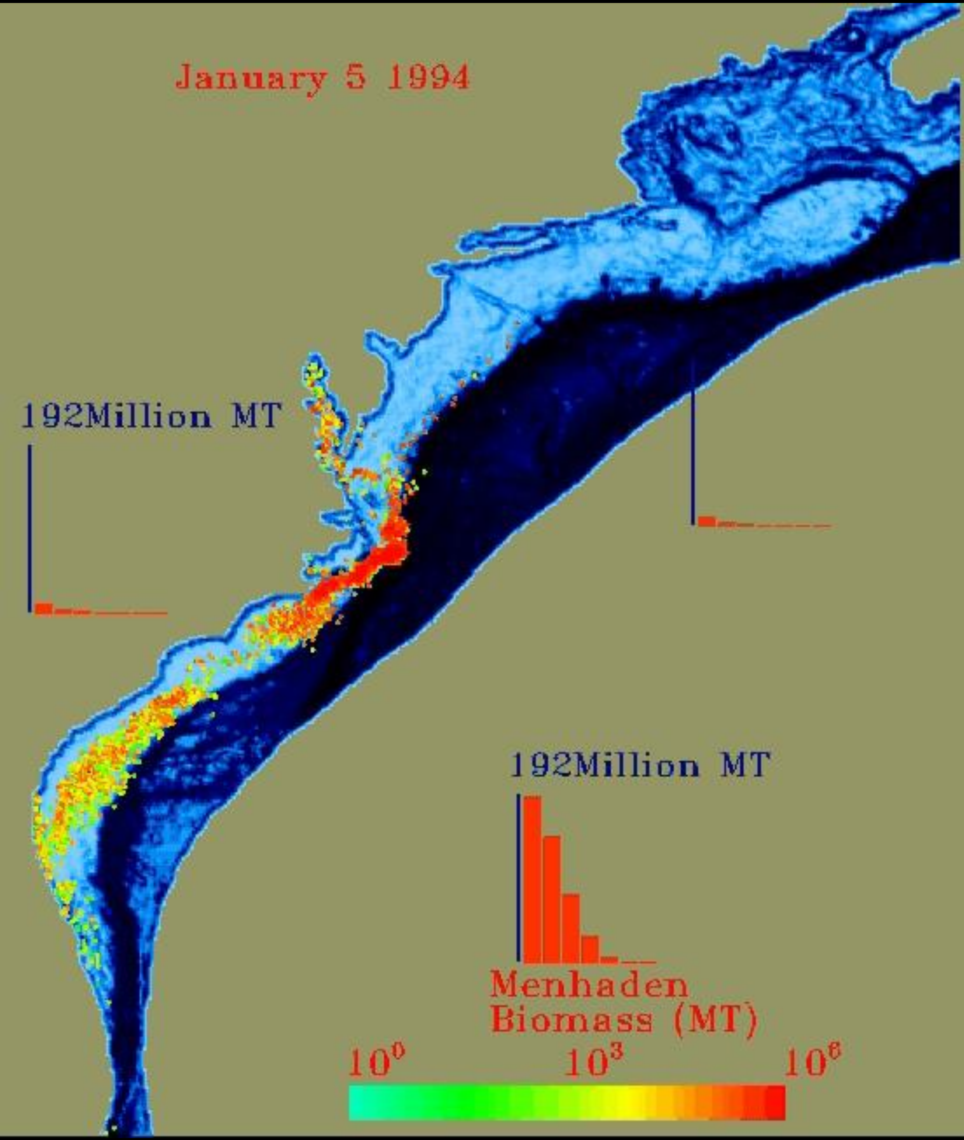
Prey Abundance

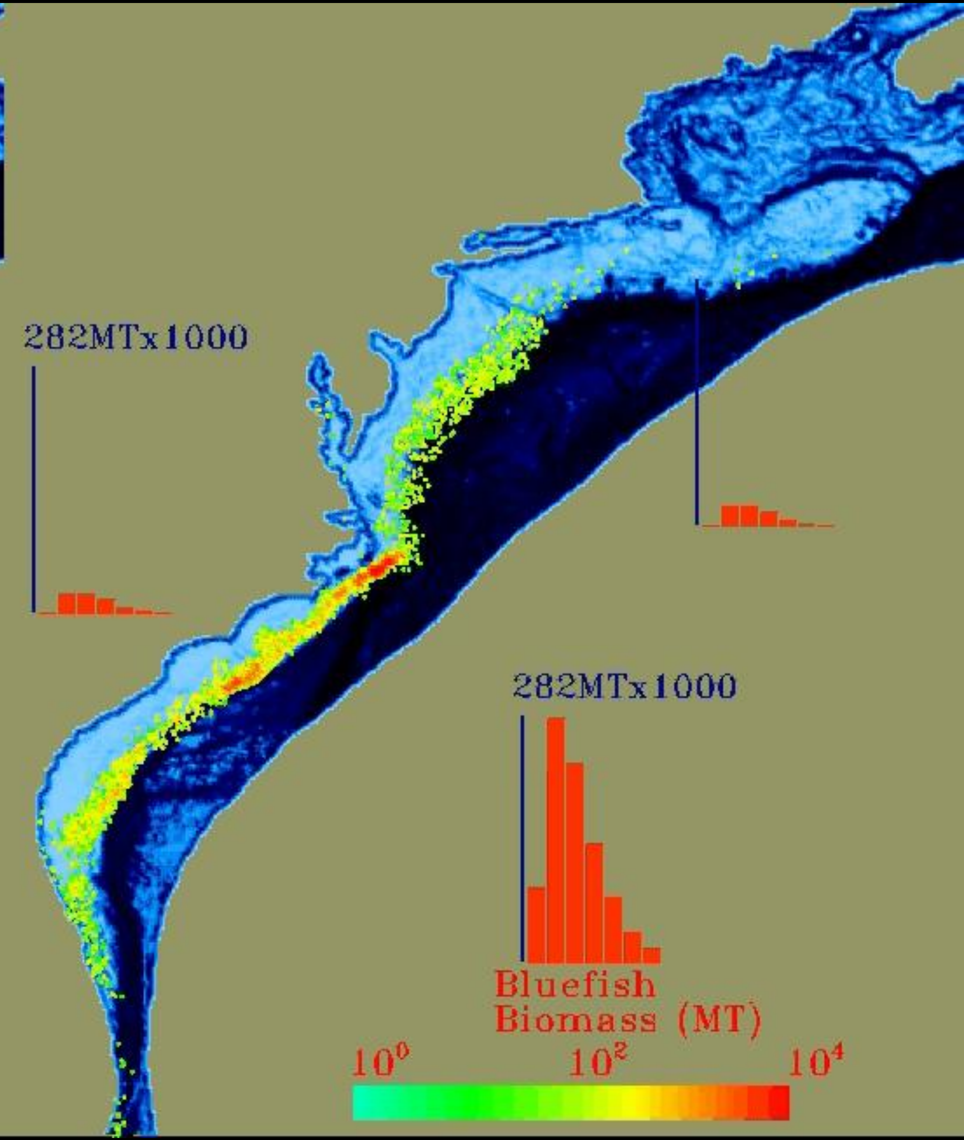


ACES (Atlantic Coast Ecosystem Simulation) Model

Menhaden Biomass

Bluefish Biomass





Summary

- Knowledge of ocean-atmosphere and ocean-habitat dynamics improve fishery assessment and forecasting. Some limitations include, for example SST & chlorophyll (no vertical profiles); spatial resolution.
- Animal tracking network can help to fill these data voids in fishery management, hurricane predictions, etc, and improve resource risk assessments.